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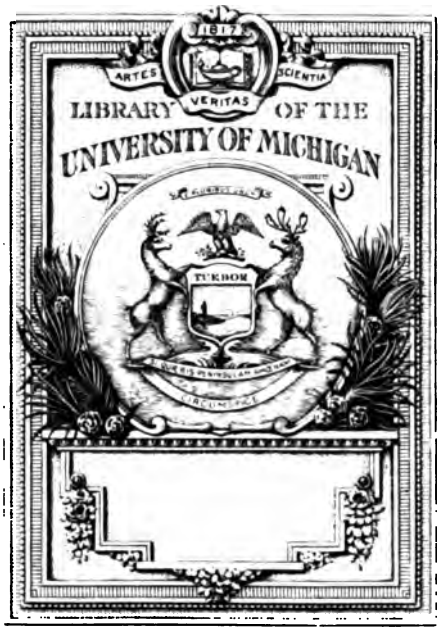
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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

AND

MUSEUM OF PRACTICAL GEOLOGY

FOR

1902.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1902.

INTRODUCTION.

BY J J. H. TEALL, M.A., F.R.S., DIRECTOR.

In England and Wales field work has been carried on in four areas, Devon and Cornwall, South Wales, the Midlands and the London District. In Scotland the work has been distributed over six districts, four of which are situated in the unsurveyed portion of the Highlands and two in the Carboniferous areas of the Midland Valley. In Ireland the Drift Survey was continued in the neighbourhood of Belfast. A few of the more important features of the work of the year will now be briefly referred to.

Highland Metamorphic rocks

In all probability the oldest rocks with which the Survey has had to deal in the course of the year occur in the Highland Metamorphic region. Previous work in the areas occupied by the Eastern Highland Schists in the north of Scotland have demonstrated the existence of extensive tracts of country composed of rocks closely resembling certain portions of Lewisian gneiss, especially those which occur in zones of secondary shearing. Those varieties of gneiss to which reference is here made consist of alternations of acid and basic material, with occasional lenticles of ultra-basic rock; but they differ from the unmodified gneisses in possessing a granulitic structure. Two belts composed of rocks of this type have been met with by Mr. Hinxman in Strathconon Forest, Ross-shire, where they are seen to be most intimately interfolded with siliceous granulites of the Moine type. Although the exact meaning of these facts is not apparent, it may safely be predicted that they will be found to have a most important bearing on the origin of the Eastern Highland Schists of Sutherland and Ross.

Other facts, which are also of importance from the same point of view, have been observed by Mr. Clough in central Ross-shire. A granitic rock has, at some early period, been intruded into sediments which have been converted into hornfels by contact action. Zones of thrusting and shearing, comparable to those which have been described in the Lewisian gneiss, traverse both

Highland Metamorphic rocks.

the granitic area and that occupied by the altered sediments, with the result that the hornfels has been "converted into mica-schists, and the granitic rocks into finely foliated augen-gneisses, with a granulitic matrix."

In the southern Highlands Dr. Peach and the officers acting under his direction have made important observations on the mainland and in the islands which form the western part of Argyllshire. The great quartzite formation of Islay and Jura, which has been split up into several recognisable zones, in some of which flattened worm casts (fucoids) occur, has been followed into Scarba, and evidence has been obtained that the boulder beds which are so well developed in the Isles of the Sea form the natural base of this group of strata. These beds contain fragments, many of which are rounded, of the underlying Degnish and Shuna limestones.

In the eastern Highland district much attention has been paid to the characters and relative ages of the complex igneous intrusions, but the different observers have not yet reached perfect agreement on this subject. Special interest attaches to this region, because the banded granulitic schists and gneisses of Moine type are here brought into relation with the quartzites, black schists and limestones of the Perthshire series. Mr. Barrow brings forward evidence to show that schists of Moine type occur between the quartzite and a persistent band which he calls the "little limestone."

Torridonian.

The Torridonian rocks may next be referred to, but it must be understood that taking them in this order is in no way intended to prejudice the question as to whether rocks of this, or even later age, may not enter into the composition of the Eastern Highland Schists. Mr. Harker describes these rocks as they are developed in Rum, and shows that they have been affected by the post-Cambrian thrust movements. In the north-west of the Island a prominent crush breccia, composed of lenticles of Cambrian limestone and crushed sandstone, overlies the thrust-plane.

Lower Palæozoic.

The detailed mapping of the Lower Palæozoic rocks on the north side of the Carboniferous area in South Wales has shown that the anticline in which the oldest rocks come to the surface follows the Towy Valley, and Messrs. Cantrill and Thomas have recognised an inversion which has had the effect of bringing *Didymograptus-bifidus* shales over Llandeilo beds.

Old Red Sandstone and Devonian.

Additional evidence of the fact that the lavas of the Lorne plateau were poured out on an uneven surface formed of the Highland schists has been obtained in the course of mapping the southern margin of this plateau to the north of Loch Melfort, and definite proof of the Lower Old Red Sandstone age of the Glencoe volcanic rocks has been furnished by the discovery of *Psilophyton* in shales which are associated with the lavas.

In England the Old Red Sandstone Rocks on the borders of the South Wales coal-field have been examined, and evidence of a powerful strike fault, or rather series of faults, traversing the central portion of the northern band has been obtained. "The course of this disturbance," as Mr. Strahan says, "along the middle

of the outcrop of the Old Red Sandstone for so many miles, its effect in throwing in patches of Carboniferous limestone by what must be an enormous displacement, and lastly, the guiding influence which it has exerted upon the rivers, in common with other disturbances, of the east-north-east and west-south-west system, all combine to give it an unusual interest." Old Red Sandstone and Devonian.

In North Cornwall the purple and green slates with *Pteraspis* which occur in Watergate Bay have engaged the attention of Mr. Reid. They are of special interest as indicating both by their fossil contents and lithological characters the existence of the Old Red Sandstone facies within the Devonian area. They are succeeded towards the south by more or less calcareous beds containing marine fossils apparently of Lower Devonian age; but these fossiliferous rocks have not as yet been traced into connection with the Mylor, Falmouth and Portscatho groups, in which no fossils have as yet been found. The Hayle sandstone, which was referred to in last year's Summary as a new group, turns out to be merely a portion of the Portscatho series.

Reference may here be made to the mining and petrological work which has been carried on in the west of England. Mr. MacAlister has examined a very large number of mining plans and reduced the observations to twenty-five inch maps, from which they will be still further reduced to the six inch and one inch maps on which the geological information is recorded. This work has supplied the Geological Survey with a large amount of information as to the form of the underground surface of the granite, the distribution of the more valuable "bunches" of ore in the lodes, the courses of the lodes and their relation to the granite and killas. Some particulars of this work will be found in the following pages, but the full discussion of the many interesting problems connected with the lodes is necessarily deferred until the surface mapping of the mineral regions is further advanced.

If we except the important paper by Mr. J. H. Collins, "On some Cornish tin-stones and tin-capels," but little work has been done on the microscopic structure of the vein-stones. Dr. Flett's report on material collected from various lodes by Mr. Scrivenor and Mr. MacAlister is therefore of special interest. In it he shows that the vein-stones have a complex history, which is recorded in their microscopic structure. Brecciation and infiltration have succeeded each other again and again, and the infiltrated material has varied in composition from time to time.

Intimately connected with the genesis of the ore-deposits is the conversion of granite into greisen by pneumatolytic action, proceeding outwards from joint planes. A very interesting illustration of this process occurs at Cligga Head, where it has been studied in detail by Mr. Scrivenor, who gives the result of his work in the present Summary.

The work of mapping the coal-fields of England on the six-inch scale has been continued in South Wales and in the Carboniferous.

Carboniferous.

Midland Counties, while in Scotland the work of revising the old six-inch maps has commenced. In South Wales the mapping of the coal-field proceeds steadily towards the west, and much information as to the correlation of the coal-seams and the nature of the disturbances will be found in the following pages. Three systems of faulting or folding exist. The steep uplift which determines the southern margin of the coal-basin and the Llanelly syncline belong to the pre-Triassic system, which traverses the vale of Glamorgan. A long series of north-north-west faults, the course of which across the pre-Triassic folds has been worked out in detail, belongs to the system which is certainly in part of post-Triassic, but probably in part also of pre-Triassic age. Lastly, a series of parallel disturbances of great magnitude, which traverse the northern part of the coal-field, the Old Red Sandstone and the Lower Palæozoic rocks, and which have determined the river drainage, may be assigned to the system of which the Neath disturbance is a well-known example. This third system, which is characterised by folding and overthrusting on a large scale, runs in a general west-south-west direction, and from its remarkable influence on the surface configuration is believed to be of later date than the others.

In the Midland District the work has been confined to the southern and western part of the Derbyshire and Nottinghamshire coal-field. Mr. Wedd has mapped out the various beds of Millstone Grit which were not separated in the original Survey, and one result of his work has been to relegate a considerable tract of country which was formerly regarded as Coal Measures to the Millstone Grit formation. Mr. Gibson has continued his researches on the higher measures of this coal-field, and has obtained additional evidence to prove that beds above the Top Hard which have been brought to light in the Gedling shafts and in the Thurgarton boring are palæontologically, lithologically and stratigraphically comparable with the higher measures occurring in other Midland coal-fields. As he points out, there seems no escape from the conclusion that the Pennine elevation, with the consequent breaking up of the syncline, was subsequent to their deposition. He has also obtained evidence of the existence of marine conditions during the deposition of the Coal Measures at several horizons, both low down and high up in the series, and in view of these facts he naturally asks whether a much larger portion of our Coal Measures has not been formed under marine conditions than is generally supposed. In working out the palæontology of the Coal Measures, Mr. Gibson has received valuable aid from Dr. Wheelton Hind, whose name frequently recurs in the following pages.

In Scotland the revision of the Carboniferous areas has been commenced in the eastern part of the Midland Valley. Mr. Wilson has re-examined the oil-shale field to the west of Edinburgh, and calls attention, in his report, to the fact that the shales in that region, with few exceptions, deteriorate both in the quantity and quality of the oil as they are followed downwards. If this should prove to be a general law, it will obviously

Carboniferous.

have a very important bearing on estimates of the value of any area in which the oil-shale horizons exist, and raise an interesting problem as to the nature of the processes by which the oil-producing compounds have been concentrated near the existing surface.

The examination of the coast between Dunbar and Cockburnspath has enabled Mr. Clough to prepare a detailed section of the Carboniferous limestone series, and to show that the beds which dip under the sea along a portion of the coast are probably very near the base of the Edge coals of Midlothian. These coals may therefore exist beneath the sea under conditions which will enable them to be worked at some future time.

But the most striking addition to our knowledge of the Carboniferous rocks of Scotland, is that furnished by Mr. Kidston's examination of a large suite of plants from the Canonbie Coal-field, in the collection of which he was assisted by Mr. Macconochie. This proves that upper, middle, and lower Coal-measures are here present. According to Mr. Kidston, the highest measures are on the horizon of the Radstock beds; an horizon which is higher than any reached in the midland or northern coal-fields so far as is at present known.

Permian and Trias.

A few facts with regard to the Permian and Trias are recorded in that portion of the Summary which deals with the Midland area; but the work of mapping these rocks over the concealed part of the Nottinghamshire Coal-field has not yet commenced. This work will be of considerable importance with reference to the future development of the coal-field, because it is certain that some of the faults which affect the Permian and Trias are due to the comparatively slight movement along important pre-Triassic dislocations. As the work of developing the coal-field proceeds, it may be possible, from a study of the faults in the red rocks and in the Coal Measures, to locate with approximate accuracy the more important faults in the remaining portions of the concealed basin. Special attention will therefore be paid to the mapping of the Trias as soon as the exposed part of the coal-basin has been surveyed.

Jurassic.

The only district where Jurassic rocks have been met with during the year is in the island of Eigg. Here marine Oxfordian with Cordate Ammonites and representatives of the Great Estuarine Series (Great Oolite) have been mapped. There is a break in the section so that the intervening stata which should consist of the *macrocephalus*-beds are not exposed.

Tertiary.

The work of surveying the Tertiary volcanic regions of the west of Scotland has been continued by Mr. Harker, who devoted his attention in 1902 to the Isle of Rum. The most interesting feature of the work in this region is the recognition of lenticular masses and patches of gneiss, usually of acid composition, but partly also of basic and composite character, These are intruded

into the Torridonian rocks which show signs of contact alteration. Their injection is evidently later than the post-Cambrian movements and is referred by Mr. Harker to the Tertiary period.

eistocene id recent.

In all areas where the work of the Survey has been going on observations have been made upon the Pleistocene and recent deposits. It is difficult to select points for special reference. Attention may, however, be directed to the work in the Belfast area, where Mr. Lamplugh and his colleagues have been occupied exclusively with the drifts, to the glacial lakes of the Tay and the Tummel described by Mr. Wilson, and to the existence of an area in the Central Highlands, where little or no glacial erosion has taken place, to which Mr. Barrow and Mr. Craig refer.

I.—ENGLAND AND WALES.

I.—FIELD-WORK.

r. 'oodward.

The ground to be surveyed was arranged in four areas, one under Mr. H. B. Woodward, and three under the District Geologists, as follows:—

1. Midland district under Mr. C. Fox-Strangways.
2. London district under Mr. Woodward, F.R.S.
3. Southern district under Mr. Clement Reid, F.R.S.
4. South Wales district under Mr. A. Strahan, M.A.

In the *Midland district* work was commenced along the southern borders of the Derbyshire and Nottinghamshire coal-fields in sheet 125 (Derby). The district memoir on the North Staffordshire coal-fields, and the memoir on sheet 141 (the Geology of the country between Derby and Loughborough), have been completed; those on sheet 156 (the Geology of the country near Leicester) and on the Cheadle coal-field are nearly ready for publication; while the district memoirs on the Leicestershire coal-field, the memoir on sheet 110 (the Geology of the country around Congleton, Macclesfield, etc.), and a new edition of that on sheet 54 (the Geology of the Oolitic and Cretaceous rocks south of Scarborough) are in preparation.

The first one-inch colour-printed map, that of sheet 123 (Stoke-upon-Trent) has been prepared at the Ordnance Survey Office, and issued in two editions, with and without drift.

In the *London district* those portions of the Thames Valley in which the brickearths and gravels had not previously been surveyed in detail on the six-inch scale have now been mapped. A special one-inch map in four sheets, with London in the centre, has been prepared at the Ordnance Survey Office, and steps are now being taken to publish these with the geological information printed in colours.

In the *Southern district* progress has been made in the survey of sheets 346 (Newquay), 347 (Lostwithiel), and 352 (Falmouth and Truro). Mining information has been obtained in the chief metalliferous district of Redruth and Camborne, and some particulars of the mines in the Lands End district have also been obtained. Mr. Woodwar

The memoir on sheet 350 (the Geology of the country around Torquay) has been completed; that on sheets 355 and 356 (the Geology of the country around Kingsbridge and Salcombe) is nearly completed, and that on sheet 349 (the Geology of the country east of Plymouth) is in hand.

An index to De la Beche's Report on the Geology of Cornwall, Devon, and West Somerset, has been printed, and will shortly be issued.*

Memoirs on sheet 298* (the country around Salisbury), and on sheet 317 (the country around Chichester) are nearly ready for publication; while another on sheet 268 (the country around Reading) is well advanced.

A colour-printed map, sheet 314 (Ringwood) has been issued.

In the *South Wales district* the survey of sheets 230 (Ammanford or Cross Inn) and 246 (Worms Head) has been completed, and work has been carried on in sheet 229 (Carmarthen and Kidwelly). Samples of coal for analysis were collected in various localities between Pontypool and Swansea.

A colour-printed map of the neighbourhood of Cardiff, to replace the hand-coloured map, is in preparation at the Ordnance Survey Office.

The memoir on sheet 248 (on the country around Pontypridd), is nearly ready for publication, and those on sheets 231 (the country around Merthyr Tydvil) and sheets 261 and 262 (the country around Bridgend) are in preparation.

The general memoir on the Cretaceous Rocks of Britain, vol. ii., is nearly ready for publication, while vol. iii. is well advanced. The memoir on the Geology of the Isle of Man is nearly ready for publication.*

Examinations have been made of new railway cuttings between Trowell and Clay Cross in Derbyshire; near Chipping Sodbury in Gloucestershire; from Grateley to Amesbury, near Salisbury; from Uxbridge to Beaconsfield, and near Wembley Park; at Chiselhurst, and from Woodford to Ilford, in Essex.

The sites of the borings for natural gas at Heathfield in Sussex have been visited, by permission of the engineer, Mr. Inverness Watts. Samples obtained from a boring for the Wrexham Waterworks Company have been inspected on the spot, by permission of the engineer, Mr. F. Storr; and a visit has been paid to the site of a boring at Goodwood.

Examination has also been made of sections whence important discoveries of palæolithic implements have been made near Ipswich and near Savernake.

* The Memoirs above noted have since been published.

I. Midland District—Derbyshire and Nottinghamshire.

Mr. C. Fox-Strangways, District Geologist.

Mr. W. Gibson, B.Sc.
Mr. C. B. Wedd, B.A. } Geologists.

CARBONIFEROUS.

Fox-Strangways and Gibson. The fieldwork during the year may be briefly summarised under two heads. Firstly, a start has been made in unravelling the sequence and arrangement of the rocks on the southern and western sides of the Derbyshire coalfield; secondly, on the eastern side much information has been obtained on the important question of the character of the rocks underlying the Triassic formation; while, in addition advantage was taken of the widening of the Midland Railway, between Trowell and Clay Cross to examine the excellent sections of Coal Measures exposed in these cuttings.

In the western part of this district the general dip of the strata is easterly; but at the southern end the beds turn up and dip to the north. The main folds of the strata, as well as the principal faults also follow these directions; the majority of the faults running in a north-west and south-east direction, but curving round to the south, and joining a series of dislocations that run more nearly east and west. These latter frequently bound the Triassic rocks along the southern margin of the coalfield; and although there is evidently much disturbance along this line, it is probable that the junction between the two formations is often unconformable, and that in many cases the Trias is banked against the older rocks.

Wedd. The anticlinal uplift shown by the inlier of Carboniferous Limestone at Crich, in the extreme north of this ground, may be regarded as the key to the structure of the neighbourhood. Its influence is shown eastward and south-eastward to Oakerthorpe and Pentrich, as far as the ground has been mapped in those directions, by the concentric curves of increasing radius into which the successive outcrops of the highest beds of Millstone Grit and Coal-measure sandstone are thrown. Its influence, diminishing southward, can be traced in that direction as far as Belper; where, as farther north, the Millstone Grits east of the Derwent Valley are gently upheaved into a low saddle; the complement of which is probably a shallow trough under and west of the river valley. North of Ambergate the eastern limb of the anticline has a steep easterly dip from Bullbridge to east of Crich; while the Kinderscout Grit of the western limb has a gentler westerly dip.

Along a north-westerly line through Lower Hartshay, passing east of Fritchley, the outcrops of the gently-folded strata are seen to form a re-entering angle in this anticlinal uplift, or the st[illegible] termination of a syncline between the eastern and southern inf[illegible]arts of it. This line is evidently a line of faulting, probably contemporaneous with the folding.

Mr. Wedd. The dip of the Coal Measures from Lower Hartshay southwards to Lower Kilbourne is a gentle one to the east. At Horsley the strike bends round to south-east and east, a change which agrees with the south-westerly prolongation of a shallow syncline proved in the Coal Measures at Denby, and apparently dying out in a south-westerly direction. This syncline which runs in a north-east and south-west direction, is well seen in the sharp bend in the outcrops of the Kinderscout and higher Grits at and north of Little Eaton, and to a greater or less extent in the outcrops of the Coal Measure sandstones. A farther indication of the intimate connexion between faulting and folding is afforded by the fact that the maximum displacement of the strata occurs where the faults cross the trough of the above-mentioned syncline, and that they diminish rapidly towards the anticlinal axis between Crich and Belper. As far as seen, all the faults of the district seem to belong strictly to the local system of folding.

The principal fault, which has been called the Horsley Fault, runs in a north-north-west direction from Morley Moor through Horsley and Lower Kilbourne, passing east and north of Belper. Its general direction is perfectly straight for six miles, but it curves somewhat in crossing alternate hard and soft strata. It has a downthrow to the north-east, the amount of which has not yet been determined; but it diminishes north-west, and possibly dies out north of Belper. From Farlawn, north-east of Belper, to a point west of Kilbourne Station it forms the western boundary of the Coal Measures; but between Holbrook and Horsley, Measures below the Kilburn Coal lie at the surface on the west side of the fault, when it crosses the above-mentioned syncline. The Kilburn Coal is cut out by the fault between Horsley and Mount Pleasant, west of Kilbourne Station. The main fault, or an important part of it, passes between Dobbs Hill Plantation and Horsley Carr to Morley Moor, throwing down higher beds of Millstone Grit against the Kinderscout Grit. Numerous faults, the majority of which have a downthrow to the north-east, run in a general north-westerly direction through Denby and Marehay. The largest downthrow is one of 90 yards to the south-west in a fault proved in the Kilburn Coal west of Denby Church.

In this north-westerly system of faulting, from Wingfield to Breadsall Moor, the prevalent downthrow, at any rate in the numerous small faults, is to the N. E., that is on the side away from the main uplift of the district.

Mr. Gibson In the country to the east, the Erewash Valley, which runs nearly in a north and south direction, is excavated on the crest of a gentle anticline bounded on the east and west by a shallow syncline of which the southern rims of each are hidden under the Trias or Alluvial deposits of the Trent. The synclines are crossed by faults having a general north-north-west and south-south-east trend, with a tendency to assume an east-west course on approaching the southern margins of the synclines; but as the examination of the colliery plans has not been completed, the further account of the faulting is deferred.

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Pendleside Series (" *Yoredale Rocks*").

dd. Only a very small portion of these rocks has as yet been surveyed; but as far as they have been mapped in the neighbourhood of Hazlewood, Duffield, Quarndon, and Breadsall, the upper part consists of a thick series of shales with occasional thin blue calcareous grits or gritty limestones (*e.g.*, in Depth o' Lumb) and numerous beds of yellow, fine, and rather coarser grained sandstone of no great thickness. Below the lowest of a group of these sandstones at the bridge over the railway cutting (Wirksworth Branch) at Duffield, a few badly preserved *Goniatites* have been found in the shale. A lower part of the series, seen from Cumber-hill, west of Duffield, to Quarndon and Allestree, consists of shales with hard fine-grained white siliceous sandstones, like the crowstones of North Staffordshire, and a few thin grey or blue calcareous sandstones or sandy limestones. *Posidoniella* occurs in this series at two horizons.

Millstone Grit.

Apart from the fact that on the published map no attempt was made to differentiate the several beds of Millstone Grit from one another, it has been found necessary in re-surveying this group to depart widely from the original mapping in the district of Ambergate, Belper, Milford and Holbrook. This departure from the former mapping is necessitated, not on account of the choice of a different divisional line between the Coal Measures and Millstone Grit, but because a considerable thickness of strata, rightly assigned to the latter in the north, and also in the south around Coxbench, was erroneously put into the Coal Measures between Holbrook and Ambergate. To this cause is due the disproportionate narrowness of the Millstone Grit outcrop shown at Belper and Milford on the old map, which, without any repetition by faulting or folding, diminishes from a width representing nearly two miles at Coxbench, to a quarter of a mile at Makeney, where the dip is scarcely greater. The Millstone Grits of the district are certainly divisible into four, if not five, different beds in the following descending order.

(*a*) A coarse-grained false-bedded grit with small pebbles, and frequently much pink felspar. This bed is often soft and porous, but sometimes hard and massive. It is white or yellow in colour, but often blotched with red or purple. The thickness probably varies.

Thin shales, generally blue and sandy. There are occasionally indications of a strong bed of gannister at the base of the overlying grit. A thin coal-seam, probably local, occurs below the shales.

(*b*) A thick fine-grained, less false-bedded, more or less micaceous grit, constant in character, and free from pebbles as far north as beyond Belper, where it perhaps becomes somewhat coarser. The colour of the grit is white, and red, or purple; parts of it are often so micaceous as to become shaly in appearance. It is more than 100 feet thick at Coxbench.

Grey shales with thin beds of hard, flaggy sandstone occur at the base.

(*c*) Fine-grained, white, and red, or purple micaceous grit, similar in appearance to (*b*), but not so thick. This grit occasionally divides into two beds. It has not yet been recognised north of Belper. Mr. Wedd.

Blue shales, in upper part sandy and light-coloured or purple with much mica and obscure plant remains. They are probably quite 100 feet thick at Milford. A seam of coal occurs below.

(*d*) A thick, massive grit consisting of lenticles of false-bedded grit of varying character, mostly coarse-grained and pebbly; white, yellow, or red in colour. Some beds, especially near the bottom, and also not far from the top, are quite conglomeratic, with pebbles occasionally an inch or more in length.

At Stanton by Dale a massive felspathic grit, which was formerly extensively quarried, emerges from beneath the Trias. This rock has been regarded as belonging to the Millstone Grit, but the only evidence for this identification is its resemblance to the Millstone Grit of the western side of the Coalfield, and to the fact of its more massive character than any sandstone in the southern part of the Coal Measures. Mr. Fox-Strangways.

Coal Measures.

On the western side of the Coalfield the Measures consist of the usual alternations of sandstones, shales, etc.; but towards the south many of the sandstones in the lower part deteriorate and thin out, or are replaced by others at different horizons, showing a diminution of sandy material in this direction as compared with the neighbourhood of Pentrich and Wingfield in the north. In the Erewash Valley the grey and black shales in the lower part of the Coal Measures contain the "Rakes" or ironstone bands, which formerly furnished the local ore but are now entirely superseded by ores foreign to the Coalfield. Mr. Wedd.

The principal coals now worked on the western margin of the Coalfield are in descending order: The Ell, the Soft, the Deep Hard, the Furnace (Lower Main or Tupton), and the Black Shale or Clod, forming a group at no great distance from each other, and the Kilburn lying at a depth of about 470 feet below the Black Shale Coal.

Below the Kilburn only one or two coals are now worked in the district, and these only at Nether Heage. The principal of these lies almost immediately above the coarse grit (*a*) and is apparently the coal mentioned by Sir Warington Smyth as the Bottom Coal.* It is now worked at Gun Lane Colliery, Nether Heage. This is the same coal as the lower of two seams formerly worked at the old Belperlawn and Nibble-and-Clink Collieries north-east of Belper; at the former, close to the surface, and at the latter at a depth of 45 yards. A level was driven through from one to the other of these collieries in the lower coal, which was a good seam nearly 4 feet thick, being nearly all bright coal. The same coal was lately exposed in the sewage excavations in Stony Lane, on the east side of Holbrook, where it was between 3 and 4 feet thick. Its outcrop can be traced at intervals from

*Mem. Geol. Survey. Iron Ores of Great Britain, Part I. p. 39.

Mr. Wedd. Ridgeway, near Ambergate, to the south end of Holbrook. Sixteen yards above this coal at Gun Lane is another seam with a roof of pyritous shale, containing numerous badly-preserved *Goniatites*.

The outcrop of the Kilburn Coal can be traced from Buckland Hollow, north of Heage, nearly all the way to Mount Pleasant, west of Kilbourne Station. South of here it is cut out by the Horsley Fault, but reappears again on the east side of the fault, south of Horsley, and is worked from the surface at Horsley Colliery, where a fish-bed with *Megalichthys* lies immediately on the coal, as also at Denby.

Mr. Gibson. Along the southern side of the Coalfield this coal can be traced almost continuously from Morley to Stanton Gate. The different layers composing the coal vary in quality, necessitating hand or mechanical sorting before delivery into the market. A strong rock, occurring at a vertical distance of 70 to 100 yards above the coal, fixes the position of outcrop. This rock frequently assumes a reddish tinge, and is then not unlike the more sandy beds of the Permian. This occasional red colour of these Coal-measure sandstones led to a somewhat higher rock, cropping out at Dale Mill, being regarded as of Permian age, though the field evidence entirely negatives this supposition.

Mr. Wedd. As the condition of deposition of the roof of the coal is of importance in elucidating the mode of formation of coal seams, the following particulars are given :—

Ell Coal.—Roof not seen. Shale below the coal contains Entomostraca, *Carbonicola* and fish scales. (Denby).

Soft Coal.—Roof dark shale with *Carbonicola*, *Anthracomya* (?), *Spirorbis* and Entomostraca (Salterwood).

Lower Hard Coal.—Shale with ironstone nodules and a few *Carbonicola* (Salterwood Colliery).

Hospital Coal.—Roof not seen. The coal is associated with strong beds of *Carbonicola* (Denby).

Furnace Coal.—Roof two-inches of ironstone, strongly oolitic, except the upper surface which is botryoidal with numerous ferruginous casts of *Carbonicola*, raised markings suggestive of worm-casts, and traces of ferns and wood (Salterwood Colliery and Marehay).

Blackshale or Clod Coal.—Roof shale with ironstone nodules containing a few *Calamites* (Heage).

Kilburn Coal.—Roof fish-bed with *Megalichthys*, under black shale. (Denby* and Horsley).

Coal below the Wingfield Sandstone—Roof not seen.

Coals at Ambergate Brickworks—

Upper Coal (with gannister floor) : Roof, pyritous shale with numerous *Goniatites*.

Lower Coal (?) roof white marl ? not seen.

Coal in railway (Ambergate and Pye Bridge Branch) at Sawmill, near Ambergate—Roof shale with ironstone nodules ; no fossils found.

Upper Coal, Gun Lane Colliery—Roof pyritous shale with badly preserved *Goniatites*. (Nether Heage).

Bottom Coal, Gun Lane Colliery.—Roof strong shale ; no fossils found.

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* At Denby Colliery well preserved plants such as ferns (*Neuropteris*), *Lepidodendron*, and fruit-cones were found in nodules thirty or forty feet below the Black Shale Coal.

In the eastern part of the district the ground surveyed during the year did not reach the centre of the syncline or outcrop of the well-known Top Hard Coal; and of the seams between this and the Kilburn Coal but little information has been gathered. The following table will, however, serve to show the distances apart and depth to the more important seams in the Mapperley district. Mr. Gibson.

Depths to Chief Coals in the Mapperley Colliery.

Name of Seam	*Depth in yards*
Ell Coal	120
Soft Coal	125
Deep Hard	133
Piper Coal	158
Furnace or Tupton Coal	196
Blackshale or Clod Coal (Silkstone Coal of Yorkshire)	248
Cannel Coal	358
Kilburn Coal	393

From an ironstone band above the Black Shale Coal, Dr. Wheelton Hind, to whom the specimens were sent for identification, recognises *Carbonicola robusta*, *C. turgida*, *C. aquilina*, and *C. nucularis*.

The associated strata consist, for the most part, of shales, and easily weathered rocks; while those of a more arenaceous character are thin, impersistent, and of a crumbling nature, rendering it impossible to trace their outcrops beyond very limited distances.

On the east side of the Erewash Valley, the strata between Awsworth and the Bramcote Hills dip continuously eastward at about 1 in 10; and, as in the extreme south-western margin the lowest horizon in the disused Stapleford Colliery lies 60 yards above the Kilburn Coal (which, by a series of downthrow faults, is increased to 260 yards in the Cossall Colliery), higher and higher measures continue to be introduced eastward. The result is that the Top Hard Coal crops out to the east of Babbington, though, in a short distance the outcrop disappears under the Magnesian Limestone, and, excepting the small inlier of Broxtowe Wood, and the narrow tongue cut through by the Midland and Great Northern Railways at Kimberley, all information regarding the character of the strata above the Top Hard has to be obtained from the sinking of coal shafts. The opportunity afforded through the courtesy of the owners and managers of the Gedling and Sherwood collieries, of examining, from time to time, the material brought to the surface during the recent new sinkings, was therefore taken advantage of.

The shafts at Gedling, situated three miles north-east of Nottingham, commenced in the Trias, to which formation the first 461 feet may be attributed; this was underlain by 47 feet of light grey Permian marls, with a breccia 8 ins. thick forming the base. The Coal Measures were then entered, of which the first 20 feet are described as "red rock," but of which specimens were, unfortunately, not seen. About 7 feet of mingled ground

Mr. Gibson. was then passed through, beneath which the shafts penetrated 100 feet of red and mottled marls to a depth, from the surface, of 637 feet, below which they were continued in ordinary grey and black Coal Measures containing seams of coal, and finally were considered to reach the Top Hard at a depth of 1,368 feet.

From the Top Hard up to a depth from the surface of about 850 feet, the rocks were mainly grey in colour, the bulk of the material being blue or grey shales, with an occasional bed of black shale associated with seams of coal, and containing numerous specimens of *Carbonicola*, together with plant and fish remains, the specific characters of which have been kindly determined by Dr. Wheelton Hind. At a depth of 1,110 feet or 258 feet above the Top Hard, a blue shale, with *Lingula* mingled with fragmentary plant remains, was met with, so that this stratum is evidently of marine origin. A similar bed (blue clunch of the sinker's record) at a depth of 844 feet, yielded large forms of *Lingula* and *Discina* in association with fish remains, consisting of scales of *Coelacanthus*, and, excepting the head portion, a nearly complete specimen of *Acanthodes Wardi*. This marine band overlies a thin coal, and to whatever origin—whether formed of drifted material or of vegetable matter grown *in situ*—the seam of coal be attributed, it was evidently quickly buried under marine sediments. Thus two marine horizons have been detected among the rocks overlying the Top Hard Coal, and, considering the difficulties attending the examination, where time did not permit a daily visit, it may well be asked if a larger portion of the Coal Measures were not deposited under marine conditions than has hitherto been suspected.

The strata, overlying the marine shale at 844 feet, consisted of grey and black shales containing a band of dark brown laminated ironstone, with many fragmentary specimens of *Anthracomya Phillipsi*. A reference to previous reports will show that exactly the same type of strata, with the same fossil, succeeds the chief coal-bearing strata of North Staffordshire on the western side of the Pennine axis. The identity in character of the Coal-measure sequence on either side of the Pennine Chain is further confirmed by the red and mottled marls which immediately succeed the shales with *Anthracomya Phillipsi*. These red beds, about 100 feet thick, so closely resemble, in all all respects, the Etruria Marls of North Staffordshire, the Brick clays of the South Staffordshire, the Ruabon terra-cotta marls of the Denbighshire, and the red marls of the Warwickshire coalfields, as well as the red marls of the Thurgarton * boring. which, in all cases, overlie the top beds of the Productive Coal Measures, that there seems no escape from regarding the Coal Measures of the Midlands as having been deposited over one continuous basin, and that the Pennine elevation, with the consequent breaking up of the syncline, was long subsequent to their deposition.

* W. Gibson. *Quart. Journ. Geol. Soc.* Vol. lvii. 1901.

Mr. Gibson.

The fact that at Gedling the Permian breccia immediately overlies the red Etruria Marls, whereas at Thurgarton the red marls are overlain by grey and red sandstones comparable to those above the red marls of North and South Staffordshire and Denbighshire, indicates that the Thurgarton boring was put down on the easterly dip and probably towards the centre of a concealed Coal-measure basin; for south of Gedling, at the Clifton Colliery, these higher measures are absent; while the Coal Measures, instead of being inclined eastward, dip northward, thus supporting the original idea held by Sir Andrew Ramsay that a syncline of Coal Measures underlies the Trent north-east of Nottingham.

The shafts of the Sherwood Colliery, near Mansfield, commence on the fringe of the Trias. Beneath this, which is not more than 30 feet thick, they penetrated the Magnesian Limestone series, also with a strong breccia at the base, and entered the Coal Measures at a depth of 251 feet, of which the first few feet consisted of brown shales with numerous plant-remains, resting on a strong reddish sandstone in which plants were also abundant. Below this the strata consisted of grey and black shales with thin bands of grey sandstone and seams of coal, the general type resembling the Gedling sequence above the Top Hard, so far as the deeper shaft had been carried (192 yards) at the time of our last visit. At 560 feet a dark blue shale (black bind), 4 feet thick, contained numerous large specimens of *Lingula*, not occurring in a single stratum but lying throughout the whole band. No trace of the red marls or underlying black and grey shales with *Anthracomya Phillipsi* were found; and there seems little doubt that the Permian of the Sherwood Colliery rests on a higher horizon than at Gedling, but definite conclusions must necessarily be left till the shafts have been continued down to the Top Hard, and more of the coalfield has been examined.

The examination of the Sherwood and Gedling sinkings shows that, whenever an opportunity occurs of searching over a large quantity of material of the Coal Measures, marine organisms are not infrequent. The same result has been obtained from the long section opened to inspection by the recent widening of the Midland Railway between Doe Hill and Clay Cross. Here, at a spot 300 yards north-west of Padleywood Farm, some grey shales containing large specimens of *Aviculopecten* (*Pterinopecten*), *Lingula*, and *Goniatites* in great abundance occur on an horizon as yet undetermined, since the surrounding area has not been examined, but situated somewhere below the Top Hard and Deep Soft, and therefore on quite a distinct horizon from those at Gedling and Sherwood.

Since this section is rapidly being obliterated the following details, giving the approximate thicknesses, are given:—

[Section Showing Position of the Marine Bands.]

(Midland Railway between Pilsley Junction and Clay Cross.)

	Ft.	In.
Pale grey shales and ironstone bands	20	0
Black shales with *Carbonicola*	6	0
COAL	3	10

Mr. Gibson.

Section Showing Position of the Marine Bands—contd.

	Ft.	In.
Grey sandy shales	8	0
Grey sandstone	3	0
Grey sandy shales	10	0
Grey sandstone	6	0
Blue sandy shales with ironstone bands	15	0
Black shales with *Carbonicola*	5	0
Light Grey sandy shales with ironstone	8	0
Black shales with *Carbonicola* and Ironstone courses	25	0
Dark shales with *Lingula*, *Aviculopecten*, *Goniatites*	4	0
Grey sandstone	8	0

The cutting is continued through several yards of strata above and below this portion of the section, but further measurements were not possible.

The chief point of interest obtained during the year in the examination of the Coal Measures, is undoubtedly the discovery of the marine character of portions of these beds, both high up and low down in the sequence. Judging from the recent work of Mr. J. T. Stobbs in North Staffordshire, and considering the very limited area so far examined in Derbyshire, other horizons no doubt await investigation; and it is hoped that they will be equally serviceable in correctly determining the position of some of the seams of coal as they have proved to be in North Staffordshire. In connection with this the occurrence of a marine bed below the Ackworth or Brierley rock in the Yorkshire coalfield* and of a simliar band below the red rock of the Sherwood sinking may be mentioned.

PERMIAN.

Considering that the area surveyed during the year contains only a very small portion of this formation, and this where it is on the point of dying out, little more can be done than to indicate the direction in which the inquiry seems to be trending. The field evidence shows most conclusively that, while the break between the Magnesian Limestone series and the Coal Measures is everywhere great, it is impossible to demonstrate any such discordance with the Trias; in fact, the evidence of the marl-pits at Cinderhill reveals the closest connection. The unconformity with the Coal Measures can be detected at the Great Northern Station at Kimberley, where the basal breccia reposes at a very gentle angle on the slightly more inclined and truncated strata of the Coal-measures. This relationship was once still more evident in the cutting at the Midland Station as described by Mr. E. Wilson. Traced southward from Kimberley, the Magnesian Limestone passes from higher to slightly lower beds; while eastwards it rests on higher horizons, until at Gedling, as we have previously (p. 13) seen, the basal breccia lies on the red Coal-measure marls occurring 286 yards above the Top Hard Coal.

The basal breccia is worthy of close attention. At the outcrop at Kimberley it is 2 feet 10 inches thick; at Gedling, which is

* Geology of the Yorkshire Coalfield, *Mem. Geol. Survey*, p. 471.

situated seven miles to the east of the outcrop, it is only 8 inches thick; while at Sherwood, near the outcrop, the thickness is 8 feet. This indicates a marginal deposit, which receives further confirmation from the coarse angular nature of the rock at Kimberley and Sherwood, where it consists of angular fragments of quartzite and large rounded and sub-angular blocks of limestone and other Carboniferous rocks: its resemblance to the dolomitic conglomerate of the Trias becoming in this case very striking. The numerous blocks of Carboniferous limestone in the breccia at Sherwood indicate that the Pennine Hills existed as a belt of high ground at the commencement of the Permian period: and that here, as in other areas, the period of greatest movement preceded the deposition of the Magnesian Limestone Series. Mr. Gibson.

Reference may be made to the small patches of Permian represented on the old edition of the Survey Map at Morley and Dale Mill. The field evidence entirely confirms the statement of Mr. E. Wilson,* that "the Permian of Morley consists of brecciated Lower Bunter and purple Lower Coal Measures, and that at Dale Mill of massively bedded Coal-measure sandstone." The latter is in fact the rock associated with the measures above the Kilburn Coal.

TRIAS.

Considerable difficulty has been experienced in mapping the sub-divisions of the Trias, both from the great unconformity which exists, and also from the very attenuated character of the beds themselves. When it is realized what a difference of altitude there must be between the crests of the Millstone Grit and other rock-features, and the troughs of the shale valleys on the pre-Triassic land-surface; and also that the total thickness of the Bunter here is sometimes not more than 20-feet, while the Keuper Sandstone is also thin, and that consequently there is frequent overlapping of the lower sub-divisions of the Trias by the higher, as well as great and rapid variations of thickness in the Bunter, it will be seen that the surface distribution of the Triassic sub-divisions must be complex. On the western side of the area the difficulty is increased by the amount of Drift which obscures the ground, and by the paucity of exposures. Mr. Wedd

BUNTER.

In the western part of the district the Bunter, where thickest, is a coarse yellow pebbly sandstone, often with strong shingle beds; but it often deteriorates into merely a few feet of gravelly sand. About Cumberhill, Quarndon, and Allestree the thicker parts are denuded into the characteristic nabs and combes. To the east of the Derwent in Croft Wood near Breadsall Station some very interesting sections of the basement beds are seen. A few feet of hard and compact fine-grained yellow strongly-calcareous sandstone, very similar to the sandy "Magnesian Lime-

* *Midland Naturalist*, vol. iv., 1881, p. 100.

Mr. Wedd. stone," mapped as Permian, a few miles farther east, underlies and apparently passes up into normal yellow soft pebbly Bunter. This hard calcareous sandstone has here at its base a thin breccia with angular fragments and hollow calcareous nodules lined with calc-spar. In one weathered section a coarse grit, full of small angular and rounded fragments of Millstone Grit and of red and green sandstone and marl, is seen, with pebbly Bunter a few feet above. The breccia doubtless represents the "Permian Breccia" farther east. It is underlain in this section by 1 foot 6 inches of white and bright red plastic marl, but whether this latter should be assigned to the Bunter or to the Pendleside shales is uncertain.

Mr. Gibson. The marginal character, perplexing variation, and great unconformity of the Trias to the Carboniferous rocks on the southern margin of the Derbyshire Coalfield, which here constitutes the chief feature of the formation, cannot be more suitably demonstrated than by giving, in brief, the relationship and sequence met with in the numerous sections between Morley and Stanton. In the cutting of the Great Northern Railway at Morley* the Triassic rocks dip westward at fifteen degrees, whereas the Coal Measures on which they rest with a natural junction are inclined to the north-east. The formation here consists of a lower portion of soft red non-pebbly mottled sandstone and bands of breccia of a united thickness of about 70 feet, overlain by about 25 feet of pebbly sandstone, succeeded by flags and marls which evidently belong to the Waterstone sub-division, since Keuper marls come in a short distance to the north. Retaining the sub-divisions of Professor Hull we have here representatives of the Lower Mottled Sandstone, Pebble Beds, and Waterstones. About two miles to the south-east in a quarry at the Hagg, a slightly brecciated and pebbly sandstone rests directly on the Coal Measures, which are to be seen in the floor of the quarry. The Pebble Beds therefore here rest directly on the Carboniferous. In the next quarry 150 yards to the south-east, we find a non-pebbly sandstone, about 50 feet thick, overlaying the Coal Measures, and succeeded by a pebbly, slightly brecciated sandstone 15 to 20 feet thick, which is overlain by thin flags and shales with a thin bed of conglomerate at the base. The same sequence is repeated in the quarries to the south, and leaves no doubt that we are here dealing with the Lower Mottled Sandstone (non-brecciated), the Pebble Beds (slightly brecciated), and the Waterstones—always supposing that the lithological characters which have been deemed sufficient to establish these sub-divisions in adjacent and other Triassic regions are here adhered to. It is noticeable that the Bunter Sandstone in the quarry is impregnated with barium sulphate, while the Keuper is not; for farther east, in the Bramcote area, this mineral has been supposed to indicate the Keuper age of the sandstones. The same sequence appears to hold good for a mile to the east of the Hagg; then, after passing a narrow break in the ground, a

* See E. Wilson, *Geol. Mag.* for 1880, p. 308.

quarry has been opened out showing red and mottled non-pebbly sandstone, 40 to 50 feet thick, succeeded conformably by about 10 feet of flags and marls with a thin bed of conglomerate at the base, and passing up into red marls which continue to crop out to the south up to the alluvium of the Trent. The middle sub-division of the Bunter thus suddenly vanishes, but makes its appearance again at Stanton by Dale half a mile to the east. Mr. Gibson.

At Sandiacre and Stapleford it forms some conspicuous crags, and appears to somewhat increase in thickness between here and Nottingham. Its junction with the Keuper to the south is very abrupt, but whether this is due to faulting or unconformity is not very clear.

To the north of the main outcrop of Trias, between Bramcote and Wollaton, detached patches of Bunter have been met with in Broomhill Wood, north of Wollaton, Balloon Wood, north of Bramcote Moor, and in the Catstone Hills, where an unusually hard conglomerate forms the capping of the hills. Between Strelley and Strelley Windmill, a belt of relatively high ground is capped with sand and gravel, but whether these result from the weathering of Triassic rocks, or belong to the Drift, the evidence is not sufficient to decide.

The capriciousness of the sub-divisions, if they can be so called, of the Bunter between Morley and Stanton is thus very evident. Their unconformity with the Carboniferous strongly reveals itself along this line, not only by the Trias resting on very different horizons, but also by the two systems being inclined in opposite directions. The idea of the Trias being here a marginal deposit at once enforces itself, just as the examination of the Magnesian Limestone series on the eastern side of the coalfield conveys the same impression, and plainly shows the gradual depression of the ancient hilly region of Derbyshire, first beneath the waters of the Magnesian Limestone period, followed by its gradual burying up by the Trias.

KEUPER SANDSTONE.

In the old quarry west of Allestree Farm, typical Keuper Waterstones are seen passing up into normal Keuper marl, but in the intermediate ground between here and Morley no sections are exposed. In the railway cutting at the latter place, thin flags of typical Keuper sandstone appearance are seen overlying Bunter. Mr. Wedd.

At Stapleford the Lower Keuper Sandstone forms a broader outcrop, the greater part of the west side of the village being built on this formation. At the east end of the village it is thrown up by an east and west fault, and caps the hill at Bramcote and at Beeston Fields. Mr. Fox-Strangways.

Between Bramcote and Lenton Park on the edge of the map the Trias is evidently crossed by an east and west fault, running along the valley separating Bramcote village from the hills to the north; while at Lenton the ground is further complicated Mr. Gibson.

Mr. Gibson. by a system of faulting that has not yet been worked out. In the Bramcote and Stapleford Hills we find little evidence in support of the Keuper age of the rock capping the Himlack Stone, Bramcote and Stapleford Hills; but we hesitate to express any opinion on this point till the ground around Nottingham and to the north has been examined.

KEUPER MARL.

Mr. Fox-Strangways This formation covers the whole of the range of hills along the southern edge of the map between Derby and Beeston. It consists of the usual red marls with many thin beds of grey skerry sandstone; which are, in most cases, too thin to trace across the country. A band near the base of the formation is rather more persistent than the others, and forms a feature that may be followed more or less easily from Derby to the Erewash Valley. In Chilwell brickyard a thick mass of this sandstone is brought up on the south side of a fault. This bed has a thickness of from 20 to 30 feet or more, and is of greater importance than the Upper Keuper Sandstones have been found to be anywhere in this district. Although it represents these in lithological character, its great thickness almost suggests that it might possibly be the upper part of the Lower Keuper Sandstone. Throughout a part of its course, the Keuper marl comes on regularly above the Lower Keuper Sandstone; but in many cases its northern boundary is very abrupt, and it is either faulted or banked against the lower formations. It dips regularly to the south; but whether the beds are broken by faults, as shown on the old map (71° S.W.) there is not sufficient evidence to prove. These faults were probably put in from apparent breaks in the features formed by the thin skerry sandstones, but these beds are far too impersistent to be a reliable guide in the matter.

The higher part of the ground formed by the Keuper marl is, in many cases, covered by Boulder-clay, and that bordering the Trent valley by large deposits of gravel, which also help to obscure the general structure of the country.

PLEISTOCENE.

Glacial.

Mr. Gibson. Considerable interest is attached to the glacial deposits of this district, from the fact that we here appear to have reached the limit in a N.W. direction of the Chalky Boulder-clay or Eastern Drift. The fieldwork has not as yet been carried sufficiently far to be sure on the point, or to be able to say what was the nature of the glacial action beyond this district along the foot of the Pennine range. Consequently, we cannot at present offer any suggestion as to the course of events that took place in this area, which appears to have been the spot where the great glacial system of eastern England impinged on the local Pennine glacier that separated it from the general western glaciation

Mr. Gibson.

The eastern ice, in its advance westwards up the Trent valley, does not appear to have possessed more force than was sufficient to push its *debris* much higher than the 400 feet contour, for chalk flints are not found much above this elevation.

That the Pennine glacier impinged on the eastern ice is clear from the fact that numerous scratched blocks of Carboniferous Limestone and Millstone Grit are found on the high ground to the south of Morley; but the absence of any relics of the glacial age within the broad basin of the Erewash Valley, though present on the surrounding high ground, is very striking, and suggests that the valley must have been held by clean ice during the deposition of the surrounding Boulder-clay.

The principal deposit of Eastern Drift, that is, clay with Chalk flints, occurs on the high ground at Risley Park at an elevation of about 430 feet. A few flints are seen in the clay about Spondon, but the great mass of this clay contains principally pebbles, and consequently is derived from the west. It is, however, of considerable thickness, a well at the village going through as much as 90 feet of Boulder-clay. This Boulder-clay extends to the north, and is found on the other side of the brook as far as Chaddesden Common and beyond.

Mr. Wedd.

In the western part of the area the Drift, for the most part, occupies ground of an altitude intermediate between the highest hills and the valleys, being found in consequence chiefly in the north of this district. It does, however, also occur on some of the higher ground and runs down, or has slipped down, into the valleys. It occupies most of the undulating tract of Keuper Marl south-east of Breadsall, but south of that village there is a considerable area of Marl quite driftless. It also partly covers the flat plain north-west of Morley and the Carboniferous shales north of Breadsall; where red Boulder-clay, sometimes overlying yellow loamy Marl, is banked against and creeps over the escarpment of the grit (*d*). Between Little Eaton and Milford a flat spread of red and brown Boulder-clay with cherts and limestones seems to cap all the high ground of Duffield Bank, entirely smothering the grit (*c*), the dip slope of (*d*) and the escarpment of (*c*) (*p.* 11). A patch of red stony Boulder-clay caps the Coal Measures between Horsley, Horsley Woodhouse, and Kilbourne. West of the Derwent some of the high ground north of Hazlewood is drift-covered. The Boulder-clay consists of red and yellow or light-grey clay, both often sandy, and presumably made of local material; the former largely made up of Triassic detritus occurs to the south-east of Breadsall, while the latter which consists chiefly of Coal-measure shales is found east of Breadsall and north-west of Morley.

The Drift over all this area is entirely local, the boulders always belonging to rocks of the neighbourhood, chiefly Carboniferous grits and sandstones, Mountain Limestone and

. Wedd. Cherts, with now and then a basic igneous rock, presumably Toadstone, and Bunter pebbles. The only place where a single north-country boulder has been found is north of Hazlewood, where a striated dark green andesite with garnets, like the basic andesites of the Lake Country, so abundant in the Western Drift, was found in some thin Boulder-clay. No trace of Eastern Drift has been found in this part of the district. There are no Chalk fragments in the Boulder-clay, but plenty of grey and black cherts occur, which might equally well be chalk flints as far as their lithological appearance goes, but the fossils found in them are invariably Carboniferous. The only indication of Glacial transport on the high driftless tracts of Carboniferous rocks is that here and there a few limestone and chert boulders may be seen. In several places high up on the flanks and edges of the Derwent and tributary valleys, there are coarse gravels with water-worn pebbles, occasionally passing under Boulder-clay. The position of these suggests their formation as torrential deposits, formed by water percolating between the edges of local glaciers and the solid flanks of the valleys. They also sometimes form esker-like ridges parallel to the valleys. At the Derby Corporation Waterworks at Little Eaton, this gravel has been found to be continuous down the slope of the hill with the recent river gravel under the alluvium. A detailed examination of samples, kindly furnished by Mr. Freeman, showed that though the pebbles of both were similar, the percentages were widely different, and the composition of the Derwent valley gravel was strictly such as might be expected considering the drainage area; while that of the Glacial gravel above the valley contained, besides other points of difference, a much larger percentage of Coal-measure pebbles. The present continuity of the two gravels is no doubt due to slipping of the glacial deposit down the slope. Except the gravel ridges, themselves sometimes obscured by Boulder-clay, the lie of the Drift is flat and featureless, with a general absence of mounds.

RECENT.

r. Fox-rangways. The post-glacial gravels and other beds of the Trent valley were noticed in the last summary for 1901, and we have little to add to that description. The 'high-level valley gravels' just come into this map to the south of Spondon, and probably occur at Beeston, but they are so intimately associated with the gravel terraces of the Trent, that no satisfactory division can be made between them. Well-formed river terraces occur west of Chilwell and at Beeston at about the 100 feet contour. These gravels are composed principally of quartzite pebbles and flints; the upper part is sometimes more clayey, and the pebbles and other fragments are often vertical, showing signs of disturbance, which has been attributed by Mr. Deeley to glacial agency.*

* *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, p. 466.

The alluvium of the Derwent valley consists for the most part of silt overlying coarse gravel. Near Little Eaton and Breadsall as found at the Derby waterworks, the silt is always about 4 feet thick, the gravel below varying from 6 to 14 feet, resting on a generally level floor of shale, with a few beds of thin grit. Near Holme Nook, south-west of Breadsall, a vegetable deposit with nuts and other plants, was found below the gravel at 10 feet from the surface. This appears to be a similar deposit to that in the Erewash Valley at Sandiacre mentioned in the Summary for 1901 (page 10) as containing recent shells. The alluvium of the Trent at Beeston is mostly gravel and varies in thickness from 13 to 21 feet. Mr. Wedd.

ECONOMIC GEOLOGY.

In the western part of the district the grits and sandstones are used for building, paving, roadmaking, and the manufacture of scythestones and grindstones; the Millstone Grit being noted for the excellence of the latter, and for building-stone where great strength and durability are required. These beds do not, however, form a lasting roadstone; the main roads of the district are generally made with the igneous rocks derived from the older formations further south. Mr. Fox-Strangways.

The principal brickclay of the country is the Keuper Marl, which is extensively worked at Derby and at Chilwell, but does not at present appear to be utilized between these points, probably from the fact of the easy railway communication which has stifled out the smaller works. The Coal-measure clays are also used for brickmaking at many places; and pottery is made from them at Derby. The Boulder-clay was formerly used for brickmaking at Spondon, but these yards are now closed.

The sands in the lower part of the Trias are used for building purposes, and a valuable moulding sand has until recently been obtained from these Measures near Stanton.

The best agricultural land is over the Keuper Marl to the south; and the largest area of arable land is consequently found on that formation. A great part of the country is, however, devoted to pasture; but, in a district like this, where the mineral wealth is so considerable, agriculture is of secondary importance.

The main water supply of the country is undoubtedly to be obtained from the Millstone Grit rocks, but a sufficient area of these beds has not yet been surveyed to show their capabilities. These rocks are tapped beneath the Trent valley in the district to the south for the supply of a large number of towns and villages between Long Eaton and Swadlincote, which is a proof that the water obtained from them is both good and abundant. The Bunter would also afford a pure water; but the beds are far too thin, and the outcrop too limited, to furnish anything more than a local supply.

2. London District.

Mr. H. B. Woodward, F.R.S., District Geologist (Acting).
Mr. T. I. Pocock, M.A.
Mr. J. Allen Howe, B.Sc.

EOCENE, PLEISTOCENE AND RECENT.

Mr. Pocock and Mr. Howe.

The mapping of the gravels and brickearths of the Thames Valley, not previously surveyed on the six-inch scale, was carried out over a large tract west of London as far as Uxbridge, West Drayton, Colnbrook and Staines, and east of London along the Lea valley to Enfield, and in the main valley to Romford, Upminster, and Grays.

A much larger area of brickearth as at Harmondsworth and Harlington has been mapped, although over considerable tracts the artificial removal of the earth for brickmaking has exposed the underlying gravel. Again in the fruit and market garden district of Heston, Feltham and Laleham much more brickearth will be shown on the new map than was represented on the old.

The attention of Mr. Newton was called to some mammalian remains from the alluvium of Staines Moor, and he has identified them as belonging to the true elk, *Alces machlis*.

Larger tracts of brickearth than had been previously recognised, have also been mapped in the Lea valley, around Ilford and South Ockendon in Essex. A new tract of chalky Boulder clay underlying the brickearth has been observed by Mr Pocock to the north of Upminster, and not far from the mass of Boulder clay beneath the gravel at Hornchurch, to which attention was first directed by Mr. T. V. Holmes.

Mr. Howe.

The *Great Western Railway* to High Wycombe and the extensions of the *Great Central* and *Metropolitan Railways* in the same district have been examined by Mr. Howe during the summer, but it is not considered advisable to publish any account of the geology until the works are more nearly completed. Most of the ground opened up is wholly occupied by London Clay, but the section of the line between the Colne Valley and the Misbourne has good exposures of Drift, London Clay (?) and Reading Beds. About Gerrard's Cross nearly 20 feet of the Drift is cut through.

Information obtained from the railway works has necessitated some minor changes in the mapping near Ickenham and Ruislip, by the introduction of a couple of patches of Reading Beds at the latter, and an increase in the existing area at the former place. Indeed, in the neighbourhood of these villages the Reading Beds appear to come very near to the surface, and probably occupy more area than can be shown by definite boundary lines.

3. Southern District—Devon and Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher.
Mr. J. B. Hill.
Mr. D. A. MacAlister.
Mr. J. B. Scrivenor, M.A.
} Geologists.

PALÆOZOIC.

Though the year 1903 will probably see the linking together of the eastern and western areas in Cornwall, yet there is still so much uncertainty as to the age of the slates in the western area that it will be convenient to deal with the sedimentary rocks of the two areas separately.

In the western area the mapping has been carried on by Mr. Hill from Falmouth and Truro, and has entailed the further examination of the Mylor, Falmouth, and Portscatho divisions, the lithological characters of which have been described in former reports. Mr. J. B. Hill.

To the west of Truro the strike of the beds bends round to the westward, as a result of which the Mylor Series is partially encircled by the Falmouth and Portscatho Series, which swing round them; this westward sweep bringing the two latter divisions within the mineral districts of Chacewater and St. Day has involved them in the mineralisation which has affected that area. The mineralisation has produced a marked change in their normal appearance in the field. For a depth of many feet from the surface, the slates are deeply tinted with varying hues of red, yellow, and pale gray, resulting from the oxidation of the iron ores with which they have been charged. As a consequence, the leading characteristics of the divisions have been masked, and their identity has to be determined from deep sections below the limits of surface decomposition.

The rather fine-grained conglomerate which occurs in the neighbourhood of Grampound and Probus has not been observed in this district west of the Tresilian River, so that its precise relations with the Portscatho Series, amongst which it occurs, has not been established. It forms a strong band however, differing in character from the small sandy intercalations so common a feature in the Portscatho Series; and it may possibly represent an unconformity.

For part of the year Mr. Dixon worked also in the same Map (352), continuing to trace the outcrops in a north-easterly direction, and helping to connect the Land's End area with that near St. Agnes. In the south-western part of this area the strike remains north-easterly, as it is around Hayle; but towards the northern edge of the Map it curves more to the east, in agreement with the adjoining district around Truro. Mr. E. Dixon.

Some purple and green silty strata which Mr. Dixon has been able to map as a definite belt between the Mylor shales and the sandy Portscatho (= Hayle) Series, seem to be equivalent, in part at least, to the Falmouth beds mapped by Mr. Hill. They

Reid. are well developed near Porthtowan and certainly extend westward to Godrevy; beyond that point it has not been found possible to map them as a separate division, partly owing to the obscurity of the ground, partly because they appear to have so thinned out as to be scarcely recognisable. Perhaps a trace of these rocks is seen in the banded silty beds in the cliff immediately west of Lelant Towans (Map 358), though within the aureole of metamorphism lithological characters become greatly altered.

J. B. Scrivenor. This work was continued northward during the latter half of the year by Mr. Scrivenor, who examined the area lying between St. Agnes, St. Allen, and Newlyn East. In the course of the survey it was found that the strike of the Hayle Sandstone curves round, to join up with rocks mapped by Mr. Hill as the Portscatho Series, and there seems little doubt that the two sandy divisions are one and the same—we can therefore get rid of the term Hayle Sandstone. As to the Falmouth Series, in this area there is great difficulty in separating it from the Portscatho Series below and from the Mylor Series above; but it it seems to be represented by the silty and often purple and green deposits mapped during 1901-2 by Mr. Dixon. The suggestion of an inverted sequence, made in last year's Summary by Mr. Reid, is not borne out, it now seeming clear that the Mylor Shales are the highest division in this area. The dip, therefore, is on the whole normal, though the strata are often folded and contorted on a small scale. Another argillaceous division makes its appearance in the area north of Perranzabuloe and Zelah, rising from beneath the Portscatho sandy beds. These "Perran Shales" are distinctly separated from the Portscatho series, as can be seen on the north beach at Perranporth; moreover, there is no difficulty in following the boundary inland, when once the peculiar weathering of these shales has been recognised. Except for a band of shales with coarse felspathic mudstones, approximately 150 feet thick, the group consists entirely of deep black and grey non-calcareous shales. The shales are best seen in the bay next but one north of Cotty's Point. The black shales appear dull and silty in section, but when a cleavage face is exposed they are seen to be lustrous; the grey shales do not show this. The banding is not always apparent, but a careful examination enables one to recognise it; and in the little bay mentioned above it is beautifully shown. A peculiarity of the Perran Shales is that the amount of quartz-veining is on the whole much less than in other divisions of the killas.

The weathering of the Perran Shales can be studied along the coast north of Cotty's Point. There is one spot, between the adit of Wheal Vlow and the Wheal Bryan Lode, where all its gradations appear in a small mass of rock. First, the dead black of the shales begins to disappear, a dull green colour gradually taking its place. This green becomes more and more pronounced as the black fades, and then in its turn fades away also, leaving almost pure white shales, a remarkable instance of bleaching.

OLD RED AND DEVONIAN.

As already remarked, great difficulty has been met with in previous years in making out the succession of the rocks in West Cornwall, where they are greatly disturbed and unfossiliferous. An attempt was therefore made in 1902 to unravel the sequence in Sheet 346, especially near Newquay. Here the rocks, though greatly disturbed, are fossiliferous, and it was hoped that a careful study of the cliffs might show the true structure and succession, and help in the determination of the age of the strata further west. A succession has now been made out, some approximate measurements have been obtained, and a beginning has been made towards the division of these rocks into palæontological zones. Much remains to be done, and the linking up with the western area is still incomplete. Mr. Reid.

The results thus far obtained are as follows:—An anticlinal arch in Watergate Bay brings up something like 1,000 feet of alternating purple and green strata, which contain *Pteraspis* and other fish-remains from top to bottom, as already recorded by Mr. Howard Fox*. This slightly calcareous mass of silt and shale is obviously of Lower Old Red Sandstone age, and is apparently also the equivalent of the purple slates of Dartmouth, as was long ago suggested by De la Beche. No base has been reached in Watergate Bay, the centre of the arch only exhibiting purple and green silts with *Pteraspis*, exactly like the strata which overlie them. Towards the upper part there is some trace of a lithological passage into the marine Lower Devonian strata; but the fossils of the two deposits are entirely distinct, and no alternation has yet been discovered. The Lower Devonian seems to rest quite conformably on the Lower Old Red. The Lower Old Red near Newquay has thus far yielded nothing but fish-remains; it contains no mollusca, no definitely marine organism, and no other fossils, unless among the obscure, badly mineralised plates may be eurypterid remains as well as fragments of *Pteraspis*. The fishes collected in the course of the Survey and determined by Mr. E. T. Newton are *Gyracanthus*? *Pteraspis cornubica*, *Parexus recurvus*? Coccostean plates, and plates belonging to an undetermined genus of ganoids. *Cephalaspis*? *Curteri* probably belongs to these beds, for the specimen in our Museum, labelled 'St. Columb Porth,' is in a matrix like that of the Old Red, and the parish of St. Columb extends into Watergate Bay. Smaller fragments perhaps belonging to the same form were collected in 1902 in the *Pteraspis*-beds.

Ignoring for the present a few feet of doubtful strata, which may represent passage or transition beds, though they have yielded no fossils, we next come to a great thickness of grey calcareous shales, which extend from Watergate Bay, past Newquay, at least as far as the Penhale Sands. Making every allowance for the repetition of the same bed through overthrusting, there would seem to be at least 1,000 feet of these

* *Trans. Roy. Geol. Soc., Cornwall*, vol. xii., p. 342, and *Geol. Mag.* for 1900, p. 145.

. Reid. strata. A series of marked beds may reappear several times, but gradually as we travel southward each successive horizon or zone sinks beneath the sea-level and is replaced by rocks having a slightly different lithological character and containing quite different fossils; the lithological change, however, is very slight and gradual.

The principal cause of the great difficulty that has been felt in making out the succession near Newquay, lies in the occurrence in great numbers of overthrust faults, all hading in the same direction, and, on the south side of the anticlinal axis, all dipping at an angle only varying slightly from that of the bedding planes in the rocks which they traverse. The southward dip varies from 30°, north of Porth, to 90° or even 95° (a slight overturn) near Ligger. If this were a true dip the thickness of the strata would be enormous; but the effect of the overthrusting seems to be almost to cancel the dip, the net result being equivalent to a flattened arch, with the strata in the southern limb dipping southward at an angle of not more than 4° or 5°. On this part of the coast there is little contortion and the cleavage being parallel to the overthrusts, nearly corresponds to the bedding as shown by the fossils.

On the north side of the arch, the strata are more confused; but the overthrusting evidently tends to cut out beds instead of duplicating them. It is interesting to notice that here the cleavage, parallel to the overthrust planes (which are inclined usually at about 45°), cuts across the bedding as shown by the fossils. Though at first sight the strata seem more easy to understand in the northern limb of the fold, yet it has been found extremely difficult to obtain a succession there—we can allow for repetition of beds; but it is very difficult to make allowances for strata entirely cut out. This northern limb of the anticline has only yet been imperfectly studied; but the beds will be noted in the description of the cliff-section as far as the succession has been made out.

Without going into much detail we will now describe the cliffs near Newquay; or rather, as this part of the coast is greatly indented and broken, we will describe shortly a generalised section at right angles to the strike, and only in a general way corresponding to the cliffs.

The crest of the anticline will be found in Watergate Bay, between Horse Rock and Creepinghole Point. The strata consist of alternating beds of purple and pale-green colour. They are fairly fine-grained, seldom deserving the name of sandstone; and sometimes the purple bands are so smooth and fissile as to merit the name of slates. These strata cannot be less than 600 feet; but they are so uniform that it is impossible to say what is the exact effect of some of the faults. Close search shows that badly preserved remains of *Pteraspis* occur throughout, the lowest yet seen being about 100 feet up in the series, close to the centre of the anticline.

On each side of the anticlinal axis these purple and green strata are followed by similar deposits containing occasional bands of

black shale full of *Pteraspis*. Gradually the purple beds dis- Mr. Reid.
appear, and are replaced by pale-green strata with rare *Pteraspis*. These pass up into alternating films of black and green shale, much silicified, and ending with a thin sandstone seen in the cliff north of Fern Cavern, and again met with on the other side of the anticline in Stem Cove. Whether these uppermost beds should be classed with the strata above or below is still somewhat doubtful; they seem to form a transition, but have not yet yielded fossils. The thin sandstone has been taken as the provisional boundary.

Next follow 50 feet of dark-grey more or less silicified slates, in which some indeterminable brachiopods occur, as well as traces of crinoids. These Lower Devonian rocks appear to be entirely of marine origin. The succeeding strata are dark grey or rarely brownish calcareous shales, with thin seams of much sheared limestone, and pale-green marly streaks, perhaps representing volcanic ash. These rocks contain numerous badly-preserved fossils, the best of which are inclosed in black nodules, proved by Dr. W. Pollard to contain a considerable percentage of phosphate. The fossils are always marine, consisting principally of crinoids, compound and simple turbinate corals, and *Bellerophon*. An abundant, but much compressed, organism, with bilateral symmetry and median septum, suggests *Calceola*, though certainly not the Middle Devonian form. This part of the series is so much repeated by overthrust faults that it is impossible yet to give any measurements. All that can be said is that the apparent dip of about 40° near Newquay is nearly neutralised by constant overthrusts from the south. Though the same bed may reappear several times, it gradually gives place to newer strata, with different fossil contents and slightly different lithological characters. The strata found at Newquay and Porth seem to reappear with similar characters and fossils on the north side of the axis in Beacon Cove.

Near the south end of Fistral Bay another set of beds is entered. These consist of harder shales, slightly calcareous, and dark grey. In them occurs 10 feet or so of highly fossiliferous, much-sheared shales and thin limestone. This bed is full of a fan-shaped or spheroidal tubular coral, not seen in other sections; it yields also obscure crinoids, brachiopods, and simple turbinate corals. The common fossil suggests *Alveolites*, or perhaps a Monticuliporoid, though it is too badly preserved for microscopic examination.

Very hard grey shale, alternating with thin grits, form Pentire Point East. These, perhaps, form the beginning of a new series, characterised by greater abundance of the pale-green calcareous seams which may represent ash-beds. The sandy beds have as yet yielded only two fossils, both of which seem to be badly-preserved lamellibranchs, one of them perhaps a *Cardiola*, different from anything in the rocks nearer Newquay. As these rocks are followed southward they dip at a higher angle and become more shattered. In them at Kelsey Head occur two thin greenstone sills (or perhaps one sill repeated by overthrust-

Mr. Reid. ing. This sill is traceable along the strike for two miles inland. Mr. W. D. Barnes, who helped in the examination of this part of the coast, made most careful search for fossils in the area south of the Gannel, but could only find numerous badly-preserved and silicified joints of crinoids, which are recognisable as far south as Holy Well. Most of them are so obscure that they can only be accepted as fossils from the occurrence with them of others slightly better preserved.

Penhale and Ligger Points show so much diturbance, with dips rising to 70°, 80°, and 95°, and shales passing into crush conglomerates, that we cannot be sure of the continuity until a larger area has been mapped. The wide tract of drifted sand between Penhale and Perranzabuloe also so masks the geology as to make it difficult to be sure of the relations between northern and southern areas. We seem to have a great thickness of grey more or less calcareous shales, probably quite 1000 feet, between the Old Red anticline and Perran Bay; but it is still doubtful whether the upward sequence is continued southward towards, and past, St. Agnes, or whether some big disturbance separates the two areas. The lithological changes in the killas of this part of Cornwall are too slight, and too much masked by shear-structures and metamorphism, for any exact correlation in the absence of clear sections or of characteristic fossils.

Mr. Ussher. The relation of the rocks just described to those of the south coast between Dartmouth and Fowey also remains to be fully cleared up; but Mr. Ussher has now been able to bring together the results of several years' work on the Devonian and Carboniferous rocks in the South Devon area. His account will be found in the Appendix.

GRANITE.

Mr. J. B. Hill. The survey of the Carn Menelez granite has been pushed westward to the parish of Wendron. The lithological character of that granite have been described in former reports. It has also been pointed out that the mass is divided by a set of major joints, trending approximately E.N.E., which corresponds with an extensive system of fissuring. In this, according to Mr. Hill, both granite and slate have been involved, by the subterranean disturbances to which the former owes its origin and the latter its deformation. That system of fissures is parallel with the axis of granite intrusion; and also with the general trend of the elvan dykes and mineral lodes, both of which latter have taken advantage of the fissures for the introduction of the material that enters into their composition.

The progressive incoming of both these conditions, in conjunction with a progressive system of fissures, is illustrated by the nature of all these phenomena in the Carn Menelez mass.

Within that granite, in the Mabe and Constantine districts, mineral lodes and elvan dykes are practically absent, while the E.N.E. system of fissuring is almost entirely confined to the visible joints. The joint faces, however, frequently display slickensided surfaces, suggesting relative displacement of the walls, and they are sometimes seen to be small faults which have

displaced the horizontal beds of granite to the extent of a few feet. Moreover the finer grained aplite veins tend to take a course parallel to these same joints. Mr. J. B. Hill.

In the parish of Wendron, which forms the central belt of the granite, this E.N.E. fissuring has been so sensibly increased that the stone which is quarried extensively in the two former parishes can no longer be profitably wrought. With this change, elvan dykes make their appearance; and an extremely attenuated set of mineral veins which have been extensively worked for tin. With the incoming of these conditions the granite, which is of coarse texture, is extensively veined by finer grained material.

The E.N.E. fissuring is no longer confined to the major joints, but the interspaces between these fissures are very closely fractured along parallel planes. Frequently they consist of tiny cracks which sever the various crystals along their course. In the next stage the cracks have been infilled with quartz, which has been followed by an introduction of schorl in association with, and finally to almost the total exclusion, of that mineral. With the oncoming of wider veins the rock takes on a banded appearance, the black schorlaceous bands standing out in sharp contrast to the granite matrix. The schorlaceous veins carry tin, and in some instances it is quite clear that the lode follows the E.N.E. joint. Over the whole district the schorlaceous bands rarely exceed a few inches in width and the lodes are correspondingly narrow. When the granite, however, is followed into the districts of Redruth and Camborne, the magnitudes of the fissures, lodes, and elvans have reached their maximum, and the marginal zones of that granite constitute the heart of the mineral area.

The mineral veins in the granite of the Wendron district are of two types—firstly, that in which the products have filled fissures by infiltration—and secondly, in which the granite itself has been partially or totally replaced by the process of metasomatis. In the latter process the first mineral to be attacked is usually biotite which has been converted into chlorite, while the replacement of felspar by quartz has followed. The final stage being reached when the product is a mixture of quartz, chlorite, and schorl, in which cassiterite plays a subordinate rôle. These two types of veinstone are however intimately related as the metasomatis of the granite is usually seen to proceed from the vicinity of small cracks or veins.

There are two masses of granite in the St. Agnes area; one at Cligga Head, the other to the west of St Agnes's Beacon. The Cligga Head mass is well exposed along the cliffs; but that near the beacon can only be seen in *situ* in two pits which were once worked for fireclay. Mr. J. B. Scrivenor.

The chief points to be noted in the Cligga Head granite are as follows:—

The joints are strongly developed, and towards the south are curved, first into an anticline, then a syncline, the southern limit of which rests on a wall of altered killas dipping at 60° to the north. To the north of the anticline they trend approximately 20° N. of E., and dip northward at about 60° N. (Both these dips are from the horizontal.) Perhaps these east and west joints would be better termed "bedding" in the granite,

Mr. J. B. Scrivenor.

since, so far as can be seen, they lie parallel to the surface of the metamorphozed killas. A second series of divisional planes can be seen, but not very clearly, trending north and south. Two comby quartz veins, very clearly defined, have a similar direction; another trends parallel to the bedding.

The granite consists of white and rose-coloured orthoclase, sometimes in porphyritic crystals, biotite, and quartz, which inclines to crystal outline in some cases, and is further remarkable for containing included crystals, often orientated to the planes of the pyramids and prisms of the quartz, which by their form, and in some cases colour and absorption, can only be referred to tourmaline. The rock connot be called coarse-grained, but the porphyritic orthoclase crystals reach one inch. Owing no doubt to the small size of the bulk of the felspar crystals, there is no definite arrangement of them along the "bedding" planes. The biotite is deep brown, and transparent when fresh in thin cleavage plates. The axial figure is only typical.

The junction of the granite with the killas on the south is very clear. The killas has been converted into a compact brown tourmaline rock, and, owing to the presence of that peculiarly stable mineral and the elimination of felspar, which has probably contributed to the formation of the tourmaline, is actually more resistent to the denudation of the sea than the granite itself; so that a bold cliff of altered killas projects beyond the granite to the west for some distance. It must be particularly noted, however, that it does not rise above the granite, so as to form a feature inland.

The junction on the north is vertical, as can be well seen in the cliff section facing in that direction. This vertical junction gave rise to a supposition, quoted by De la Beche, on the part of miners, that the granite had been intruded as a big dyke; but from later evidence, obtained from a Mine Report dated 1857 and 1858, there can be no doubt that this is a faulted junction and that the main mass of the granite, which is the faulted portion, has been lowered at least 300ft. The fault, then, is one of the great cross-courses, but differs in this point—that the downthrow has been vertical and not complicated by any appreciable horizontal movement. The fault does not affect the whole of the eastern outcrop of the granite, but only the northern part; that part should then be looked on as part of the main mass; while the southern part, as can be seen both by the form of the "bedding" and the nature of the islets in the sea to the west, is a short apophysis intruded horizontally into the surrounding killas.

Near the south junction the granite is modified: small veins of orthoclase, of quartz, and of large thin crystals of biotite, as much as ½in. in diameter, are frequent.

The most interesting point however in the petrology of this mass is the metasomatism along the "bedding" planes, resulting in the production of a band of greisen on either side of the fissure, which is itself filled by a quartz vein, generally rich in wolfram and tin, with some mispickel and basic sulphate of copper derived probably from copper pyrites. The "bedding" planes are not a great distance apart and the greisen extends in some cases several inches from the quartz vein, so that the cliff

presents a peculiar striped appearance. Actual measurements of some of the greisen bands from side to side, and of the unaltered granite in between, give these results:— Mr. J. B. Scrivenor.

Greisen.	Granite.
20 in.	3 in.
6 „	5 „
9 „	20 „ (N. part of mass only.)

The greisen bands are frequently less than the above. None greater than twenty inches were measured.

There is no alteration along the north and south joints.

Although the bands of greisen in the cliff section are well defined, the passage from granite to greisen is seen to be gradual in the microscopic section, the change being marked by the gradual disappearance of the orthoclase, which is replaced by secondary silica and muscovite. The form of the original felspar crystals can often be clearly made out in the greisen. In the granite the orthoclase is never fresh; not only is it turbid with kaolin, but secondary muscovite and silica are present to a greater or less extent. The biotite too, is not perfectly fresh: near the greisen bands it is almost completely bleached, with a faint trace of vandyke brown. The absorption is strong — vandyke brown — colourless. It contains some titanium, as is shown by the presence of crystals of rutite: these, however, are not common. Tourmaline is abundant as ragged brown and blue crystals. It frequently contains included zircons and dark grains which are indeterminable; both of these are surrounded by well-marked pleochroic halos. In many cases, if not all, the tourmaline has taken the place of the biotite, both in the greisen and in the granite near its junction with the former.

The greisen contains quartz of two generations; the original quartz of the granite with orientated tourmaline crystals and occasional minute zircons and very good fluid cavities; and secondary quartz derived from the felspar and mica, without orientated inclusions, but easy to distinguish from the original quartz, not only by the smaller size of the individual grains, but also by the greater abundance, though more minute dimensions, of the fluid cavities. A little of the original biotite is left, almost completely bleached, but showing strong pleochroic halos; the bulk of it has been replaced by tourmaline. Cassiterite is not uncommon: a portion of the rock crushed to powder and separated in cadmium borotungstate yielded a considerable quantity. The mica is chiefly muscovite; but another occurs in small nests not derived from the felspar, with brilliant polarizing tints, but colourless. Owing, however, to the difficulty of separating this with certainty in heavy liquids from the muscovite, it is impossible to determine its exact nature; seeing that lepidolite occurs coating the sides of the fissures nearer the junction with the killas to the south, it may be that this also is lepidolite; or again, it may be gilbertite, a mica hard to separate as a distinct species from muscovite. Gilbertite is mentioned by Dr. C. Le Neve Foster as occurring at Cligga Head. Lastly, topaz, in irregular colourless grains, rarely seen with crystal outlines or cleavage, is abundant throughout the greisen bands.

Near the junction with the killas to the south, the greisen bands become more frequent and thinner. Sometimes they cannot be recognised along the "bedding" planes, which, independently of the presence or otherwise of the greisen, are frequently coated with crystals of lepidolite, pink orthoclase, colourless topaz, wolfram, and cassiterite, the usual vein of quartz being absent. One specimen was collected of a joint face coated with a continuous mass of topaz crystals, which might be easily passed over as quartz.

Whatever may have been the medium, whether vaporous or fluid, which caused the metasomatism of the granite, it is evident that it must have been rich in boron and fluorine.

Mr. Reid and Mr. Scrivenor. being associated in some way with masses of ironstone containing garnets, both at this point in the neighbouring ironstone mines. Neither the greenstone nor the associated killas show any metamorphic spotting and the locality seems to be fully three-quarters of a mile outside the metamorphic aureole. A fuller petrological examination will be made.

MICA TRAP.

Mr. Reid. A group of small dykes of Mica Trap or Minnette form a noticeable feature between Newquay and Holywell Bay, and traces of a similar rock have been met with near St. Allen, connecting the Newquay outcrops with those near Falmouth. The behaviour of these dykes is very different from that of the elvans; instead of following straight lines of fracture they zig-zag irregularly along joint-planes in the killas, widening and narrowing very abruptly. As a rule the rock is much decomposed; but a quarry on the north shore of the Gannel is now being worked down to the water-level for road-metal, and has yielded stone better preserved than any that has previously been obtained in Cornwall. Some slides of this rock were prepared last summer by Mr. Barnes and from them Mr. Scrivenor has drawn up the following description:—

Mr. Scrivenor. The rock is of fairly uniform grain, and panidiomorphic; but the felspar tends to form a ground mass. This felspar is orthoclase, sometimes well-preserved. There is no reason to suspect the presence of a plagioclase felspar. The ferromagnesian constituents are: biotite, largely altered to chlorite, epidote, and magnetite: calcite also appears in association with this mineral; colourless augite, in short idiomorphic prisms, and brown hornblende, twinned parallel to 100, sometimes polysthenically. A little interstitial quartz and calcite occurs, and some apatite. The amount of hornblende and augite varies considerably in different specimens. One section shows an enclosed mass of granitic quartz and orthoclase, the former with a well-marked reaction rim. The rock is remarkable for the presence of three ferromagnesian minerals, and, according to Rosenbusch, must be called an augite-hornblende-minette.

METAMORPHISM.

The metamorphism caused by the granite masses is better seen in the case of the Cligga Head granite than the St. Agnes mass. An aureole was mapped in both areas; but it must be remarked that owing to the peculiarly sporadic nature of the spotting at a distance of about one mile from the contact, such a line is extremely vague. In the case of the Cligga granite, however, the aureole may be said to be fairly well defined. Walking south-west along the Perran Sands, one first encounters spotting near the Wheal Vlow adit. Until the bay immediately west of B.M. 269.8 on the sand-hills is reached, it is very sporadic and easily passed over; in that bay, however, the spots become more defined and more numerous. So far there has been no other evidence of metamorphism. On crossing the stream to the Chapel Rock and the cliffs adjacent however, not only are the spots found to have increased both in size and number, but a general bleaching of the shales and mud-

stones have set in. Still the dark and light bands of the mudstones may be made out; but in the case of the Portscatho it is already hard to distinguish the thin shale bands, a difficulty which increases as one approaches the granite; indeed, were it not for a portion of the killas at Wheal Prudence being silicified, thereby revealing again its composition, it would be hard to recognise this pale altered mass as the Portscatho Series. It was found, however, that careful examination enabled one to identify the original shale bands. Some of this bleached killas with strong spotting was powdered for microscopical examination, but no secondary minerals were found; nor do the spots develop into any mineral in this aureole. Definite tourmaline rock was seen first between the Shag Rock and the boundary of the dynamite factory; between these and the actual junction it does not occur again. Spotting and bleaching of varying intensity are developed in all the killas *débris* on the dynamite factory. The projecting cliff at the south junction affords as good an example of tourmalinization as could be desired. It does not appear to extend more than a few feet, giving place to the same phenomena of spotting and bleaching observed on the other side. Mr. Scrivenor.

It will be observed from the relation of the form of the aureole to the existing mass that there must be a considerably greater mass now covered by the sea and extending toward the north-east.

In the St. Agnes aureole the spotting is as greatly developed as in the Cligga aureole; but the bleaching is not so marked, the killas being of light shades of red, yellow, and grey, besides being indurated slightly. At two localities, bodies, evidently due to the proximity of the granite, were found which resemble chiastolite, but which do not hold out any hopes of certainty.

The elvans, with one exception, produce nothing more than a slight hardening macroscopically; microscopically, a section, from an elvan in Mr. Reid's ground, shows small prisms of indigo-blue tourmaline and muscovite, which may or may not be secondary. (Gravel Hill elvan, Perran Sands.)

The exception is in the big quarry on the cliff near Bawden Cottage at St. Agnes. Here a piece of brown tourmalinized killas was found at the junction. The tourmalinization did not appear to extend beyond half an inch, although no doubt a microscope section would reveal a much greater limit.

A mica-trap at Towan Head, Newquay, although more basic, and therefore it may be reasonably presumed, injected at a lower temperature, has had the effect of altering the Newquay shales in such a way as to resemble those altered tuffs known as "Hälleflinta." The alteration extends several inches from the margin of the dyke; this may be explained, however, by the fact that the dyke has many ramifications.

QUARRIES.

The parts of Cornwall examined in 1902 only supply road-metal and building stone for the immediate neighbourhoods. Mr. Reid.

Mr. Reid. Most of the elvan dykes have been worked for road-metal, and also for building-stone; which has been a good deal used in Newquay; though the hard flat-bedded killas is generally preferred. The elvan used for building is commonly the buff weathered rock near the surface, the harder and tougher grey rock usually occurring lower down, being only reached in a few of the quarries. Some of the much altered and silicified elvan is very tough close to the surface and makes good road-metal; though the main roads around Newquay are metalled with a highly-altered killas from the metamorphic area near the granite margin at Roche.

MINING.

Mr. J. B. Hill. Although the districts surveyed have formerly been the seat of extensive mining industries, few of the mines are at present active. Tin is still profitably mined at St. Agnes, and trials are being made for silver-lead and ironstone in a few other places. In the valley between Redruth and Carn Brea the washings from the mines are extensively treated by modern machinery and large quantities of tin recovered that would otherwise find its way to the sea; and works on a smaller scale are active in the valley at Bissoe. Tin streaming in the original sense of the term is practically a thing of the past, but an occasional tinner may still be seen working over the old stream works on Porkellis Moors. In the same neighbourhood the old lodes are occasionally worked on a small scale. At the present moment Wheal Enys near Porkellis is being profitably worked by two miners at a depth of 12 fathoms, where a string 8 inches in width carries tinstone estimated at 3 cwt. to the ton.

In the last few years the *débris* from the mine burrows has been put under the stamps, more especially from those mines that were originally worked for copper, in which the tin ore was neglected. In the Bissoe valley, at Twelve Heads, the materials from such burrows are at present being stamped. The burrows from the United mines in that district have been recently worked on a large scale, but unfortunately these operations have had to be discontinued.

The ochre works in the Bissoe Valley have been in continuous operation for upwards of forty years. The main county adit discharges into the stream above Bissoe, and the oxide of iron carried in suspension, after being collected in pools, is pulverized, washed and dried, producing a fine brown ochre.

In the same locality works exist for the refinement of arsenic, the crude material which is calcined at the mines and recovered in flues being sent thither for final treatment.

Mr. MacAlister, who joined the service at the end of April has been engaged for the greater part of the season in the laborious task of reducing the mining information from the working plans to the survey maps. These duties have been undertaken at Camborne, Truro, and the Home Office in London. At Camborne he has been largely indebted to the authorities at Dolcoath,

who have placed office accommodation and all facilities for the work at his disposal. To Messrs. Henderson & Sons, of Truro, the survey is under a similar obligation, while at the Home Office he has been indebted to Mr. W. W. Ware, of the Mining Record Department, for valuable assistance in the prosecution of the work. Mr. J. B. Hill.

The reduction of the mining plans, referring to sheet 352, which includes the Camborne and Redruth districts forming the heart of the Cornish mining region, is now well advanced; while considerable progress has been made with the Land's End sheet to the westward (351).

For the last two months of the year, Mr. MacAlister was engaged in the examination of the mineral district of Camborne, but more particularly in the investigation of the lodes of Dolcoath, and of the Great Flat lode, which may be said to constitute the type lodes of that area. Mr. MacAlister.

The relation of the mineral lodes to the granite and killas of the Camborne area will be seen by reference to the accompanying diagram.

The study of the mining plans shows the upper surface of the granite to be a gentle dome, occasionally broken by horizontal furrows or ridges.

The lodes, which are usually steeply inclined, traverse both killas and granite alike, but the mining in the area is mainly confined to the raising of stanniferous ore from the deeper portions of the lodes that lie within the granite.

Underground investigations, combined with examination of the plans, afford very limited information of the subterranean courses of the elvans. They appear, however, to be patchy and discontinuous, and of variable dip, and more frequently hade to the north than to the south.

It is noteworthy that a part of the outer belt of the granite for a thickness of about 150 feet, in the neighbourhood of the Great Flat lode, is much decomposed, notwithstanding its depth from the surface. The decomposed material is largely kaolinized, and is also schorlaceous.

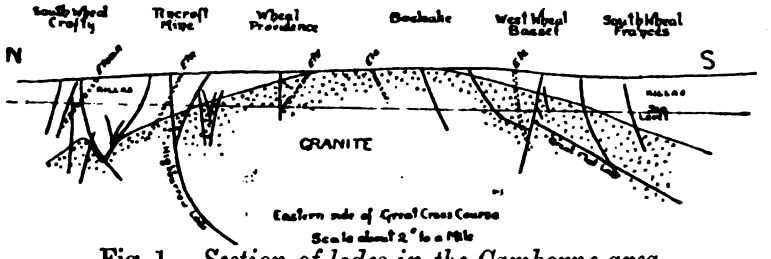

Fig. 1.—*Section of lodes in the Camborne area.*

The lodes, which trend approximately E.N.E., are crossed by a system of N.N.W. faults, which displace the killas, granite, elvans, and lodes. A noteworthy feature is the tendency for the lodes of the Camborne area to curve towards the south, in depth, notwithstanding that their upper extensions may hade to the north (see diagram). In marked contrast to the usual high

Mr. Mac-Alister. prevailing dip is the low hade of the Great Flat lode; in its easterly extension, however, it appears to revert to a normally inclined lode, in Wheal Uny.

The Dolcoath group of lodes shows a marked tendency to branch in an upward direction, so that the main trunk occurs at depth; and this group hades steeply to the southward. Their walls are by no means sharply defined, but the hanging wall is the most definite. The lodes occasionally divide and re-unite again at depth. The enclosing rock, or "horse," may be of great magnitude; at Dolcoath a "horse" occurs 240 feet in length, the depth of which has not yet been definitely ascertained. It is considerably impregnated with cassiterite, usually in the form of minute strings.

The well known disposition for the ore to occur in concentrated patches along the lode, known as "bunches," is further characterised by the tendency of these bunches to assume a general easterly hade, oblique to the trend of the lodes in which they lie, and a series of bunches in one lode has its counterpart in adjoining lodes.

The N.N.W. fault, locally known as the Great Cross Course, heaves the Dolcoath main lode 74 fathoms, while a mile further to the south it heaves the Great Flat lode but a few fathoms. It would appear, therefore, not to be a simple vertical displacement, but that it involved a tilt from the horizontal, which varied on either side of the fissure.

In the appendix (p. 154), Dr. J. S. Flett has described the microscopic characters of the ores.

4. South Wales District. Glamorganshire and Carmarthenshire.

Mr. Aubrey Strahan, M.A., District Geologist.
Mr. B. S. N. Wilkinson.
Mr. T. C. Cantrill, B. Sc.
Mr. E. E. L. Dixon, B. Sc.
Mr. H. H. Thomas, B. A.
} Geologists.

Mr. Strahan. The work of the past year has lain between Llandilo and Carmarthen, in the north, and around Cross Hands, Llannon, Llangennech, Llanelly and Pembrey in the coalfield.

The surveying of the Ordovician and Silurian rocks and Old Red Sandstone on the north side of the Carboniferous area has been continued by Mr. Thomas and in part by Mr. Cantrill; that of the northern part of the Carboniferous area, including the North Crop of the coalfield by Mr. Cantrill; the central part of the coalfield by Mr. Dixon, and the southern part by Mr. Strahan. Mr. Wilkinson was engaged, after the completion of Gower, in a tract lying west of the coalfield.

Ordovician.

Mr. Cantrill and Thomas. A brief examination of some rocks at Maes-y-falien, which appeared to overlie Llandilo Flags, has shewn the existence of inversion; the doubtful strata being in reality the Ffairfach Grit

and *Didymograptus-bifidus* shales emerging from beneath the Llandilo Flags. From his work upon these rocks westwards along the Vale of Towy Mr. Thomas has been able to furnish the following remarks, the subdivisions being in ascending order:— Mr. Thomas

The *Didymograptus bifidus*-beds maintain their character as black shales and sandstones. They are probably in contact with the Silurian rocks almost as far west as Llanarthney, and are poorly exposed at Troed-y-rhiwgoch, but for the most part are concealed by drift.

The *Ffairfach Grit* appears to be truncated westwards by an offshoot of the fault which forms the Silurian boundary. The Llandilo beds which form the southern limb of the Llandilo anticline all in turn run obliquely up to this fault, and so far have been seen no more on the south side of the Towy.

The *Llandilo Flags* on the north side of the Towy pass up into some unfossiliferous shales; traced westwards they pass horizontally also into shales, with less frequent limestones—at the same time brachiopods become less common, but graptolites of the type of *Didymograptus Murchisoni* begin to abound.

The *Dicranograptus*-Shales appear to be represented by some black shales with thin cherty or gritty bands, which are faulted against Llandilo beds near Dryslwyn and Cilsân, but which have yielded no fossils.

A series of pebbly grits, conglomerates and mudstones comes in west of Llanarthney, and locally contains Tremadoc trilobites. The rocks have been thrown into a series of east and west folds and are probably also much faulted.

SILURIAN.

The lowest Silurian rocks seen in the valley of the Cîb, though resembling the Wenlock mudstones, contain some Upper Llandovery forms, such as *Pentamerus undatus*, *Petraia*, etc. Above them comes a great mass of greenish mudstones at the base of which Tarannon Shales may possibly be represented. Mr. Cantrill

The whole of the Silurian group is truncated by the Old Red Sandstone westwards. The upper part, which becomes increasingly sandy westwards, is the first to go, and the Lletty Grit follows, leaving only some mudstones with *Atrypa reticularis* etc. Lastly these also disappear about a mile west of Middleton Hall. The truncation may be attributed in this case possibly to unconformable overlap. There is reason to think that the lower members of the Old Red Sandstone are themselves overlapped by higher members, as were the Tilestones further east. Mr. Thomas

OLD RED SANDSTONE.

The lowest member of the Old Red Sandstone consists of fissile sandstones and marls, with a prevailing green tint, due apparently to the presence of chlorite which can be recognised sometimes in large quantities. They are about 450 feet thick and are followed by the great mass of marls with dull-red sandstones which constitutes the bulk of the lower sub-division of the Old Red Sandstone. Mr. Thomas

Above the marls come the Brownstones, in which it is possible to distinguish the highly micaceous green and red sandstones and marls of the Senni Beds, though there is no break between Mr. Cantrill and Mr. Thomas

r. Cantrill d r. Thomas. them and the beds above or below. Though sandstones are subordinate to marls, the Brownstones form a bold escarpment south of the Gwendraeth Fach.

The uppermost member consists of about 150 feet of pebbly sandstone with bright-red marls. Though generally red the sandstones often have a yellowish or olive-green tint, especially towards their top where they pass up into the Carboniferous rocks.

r. ilkinson. The Old Red Sandstone of Pendine and Laugharne consists in the main of marls with a poor representation of the Brownstones. The topmost beds consist of pale-green micaceous flags which pass up into the Carboniferous Limestone, the conspicuous conglomerates of Gower being absent. The marls contain grits and some compact cornstones; many of them are honeycombed by the cavities left by the weathering out of calcareous concretions.

A large part of the series is admirably laid open to examination in the cliff between Llanstephan and the Tâf. Here also may be seen a great disturbance which descends the Gwendraeth Valley and passes Llanstephan in a W.S.W. direction across the promontory. Parallel to it, half a mile further south, there is a small anticline accompanied by some small overthrusting. North of the disturbance the Old Red Sandstone rises northward in gentle undulations.

In Gower, the examination of which was completed during the past year, it was found that the uppermost white conglomerates are probably present in Rhossili Hill, though they are not visible. The base of the marls almost certainly lies below sea-level, making it certain that there is a great mass of the lower Old Red sub-division present in Rhossili Hill which is absent in Cefn-y-bryn. Some small excavations on Cefn-y-bryn, made in the hope of exposing the base of the Old Red Sandstone, led to no definite result beyond showing that the junction with the Silurian Rocks is sharp.

CARBONIFEROUS.

Carboniferous Limestone.

r. Cantrill d r. Thomas. The Lower Limestone Shales are visible in one place only in the main escarpment, namely, at Banc-y-mansel, but are exposed in a faulted outlier at Bryn-yr-odin, which is referred to later on. They may be about 30 or 40 feet thick.

The lower half of the Main Limestone consists in part of dark oolite. It forms a bold escarpment and has been much quarried. The light-coloured oolite above it continues but is less distinct, while the sandstone which ran at its base has disappeared. Upon the light oolite there rests a bed of yellow and red marl about 30 feet thick, which may be compared with a stratum resting on a white oolite in Monmouthshire.* It contains lumps of

* Geology of the Country around Abergavenny, pp. 23-25 (1900).

oolite and crinoidal limestone near its base. The limestone above is dark and cherty, and occasionally oolitic. Mr. Cantrill and Mr. Thomas

The Rottenstones are poorly exposed near Banc-y-mansel and at Garn. The decomposed cherts have been worked for plastic clay near Gareg Gwenlas and Garn.

In Gower the Lower Limestone Shales are shown in a nearly vertical position near Rhossili where they are faulted against Old Red Sandstone. They consist of fine shale with thin bands of limestone, which sometimes pass into rottenstone, as at Pitton Mill. Dolomitisation along bedding-planes is particularly well exhibited at Overton Mere, near Port Eynon. The outlier of limestone at Black Rocks, west of Llanstephan, consists of dark-blue limestones with grey shales, all belonging to the Lower Limestone Shales; they lie nearly horizontally upon greenish micaceous sandstones, but the junction is concealed. The more massive limestones have been burnt for lime. A second outlier at Honey Cors Farm, south-west of Laugharne, consists of massive blue and light-grey limestones, which are largely quarried for burning and road-metal; the Lower Limestone Shales, if present, must be represented by limestones. Mr. Wilkinson.

At Pendine, a natural passage can be followed up from the Old Red Sandstone into the Lower Limestone Shales, which resume their normal aspect. The Main Limestone, consisting of evenly-bedded, often massive, blue limestones, forms a bold cliff west of Pendine.

Immediately to the west of Dolwen Point there occurs a remarkable conglomerate in the limestone, the sequence of strata being as follows:— Mr. Strahan

At Pendine Steps.

Even-bedded, black limestone, in beds of 1 to 3 feet thickness; the base undulating so as to fill up inequalities in the underlying surface, the top straight.

Lumps of black compact limestone imbedded in a granular calcareous matrix, with some lenticular seams of yellow calcareous sand passing down into

Yellow calcareous rock containing large and small lumps of various kinds of limestone, some red, some coarsely crystalline, some oolitic. In places the rock is laminated; in others it contains harder bands which are disturbed and broken, and which are truncated by the black limestone above, as though by an unconformity. Much of the rock has a gravelly aspect, and in its upper part there is some fine gravelly conglomerate full of well-rolled limestone fragments.

Massive light-coloured limestone of saccharoid texture.

The thickness of the conglomeratic series amounts to about ten feet, but its base is ill defined, owing to the breaking up of the surface of the massive limestone below it.

The folding and breaking up of parts of the yellow rock suggest, at first sight, subsequent movement, but the abundance of well water-worn fragments of limestone, and the manner in which the overlying limestone adjusts itself to the uneven surface on which it was deposited, proves the contemporaneous age of the structure.

Millstone Grit.

Mr. Cantrill and Mr. Thomas. In the North Crop the Millstone Grit presents the same features as heretofore except that there appear to be several shale bands interbedded with the basal grits. Upwards the subdivision passes into the Coal Measures, and the Farewell Rock having lost its massive character, the dividing line between the two becomes most indefinite. Generally the sandstones near the top of the Millstone Grit are hard and olive-green, the highest occasionally becoming a quartz-grit, but similar rocks recur at higher horizons, in what must be considered Coal Measures.

The basal grit of this region is devoid of pebbles, and has been dug for "silica sand" wherever it is sufficiently rotten. The aspect of the shales which constitute the middle member of the Millstone Grit has led to useless trials for coal or mine.

Mr. Strahan. The finest exhibition of the Millstone Grit in this region occurs at Ragwen Point, near Pendine. It shows a return to the Monmouthshire type, but differs totally from that observable at Bishopstone in Gower.* The grit rests upon a thin-bedded limestone with chert, and with numerous partings of shale, much resembling the "black lias" of Oystermouth. About 80 feet of grits and shales are exposed, the latter occurring in three bands, each of which make a ledge in the cliff. Septaria of smooth black limestone with *Lingula*, and calcareous or pyritous bands occur in the shales, but the fossils observed in Monmouthshire † were not detected. Some of the grits are coarse and contain small pebbles.

Coal Measures.

An account of the part of the coal-field which has been examined during the past year will be found in Appendix IV., p. 170. The area includes the neighbourhoods of Llanelly, Pembrey, Llannon, Cross Hands and Pontyberem. Among the questions which have arisen for solution may be mentioned the existence of a series of great easterly downthrows along the coast, and of westerly downthrows along the North Crop; the existence of some remarkable structures ranging south-westwards from Ammanford, in which over-thrusting is prominent; and lastly, the continuance of the Llanelly syncline under the foreshore westwards, and the limit of the areas occupied by the seams which have yielded the bulk of the coal near Swansea and Llanelly.

FAULTS AND DISTURBANCES.

Mr. Thomas. The general west-south-west strike of the Silurian and Ordovician rocks continues through most of the area examined during the past year, but is curiously deflected near Nelson's Tower (Middleton Hall). Swinging first to W. 20° N., it then

* Summary of Progress for 1900, p. 87.

† Geology of the Country around Abergavenny, p. 47, 1900.

resumes its normal direction, making a curve about a mile and a half in length, and convex to the north. Thence to the western edge of Sheet 230, the strike runs W. 30° S. The lower beds of the Old Red Sandstone follow this curve, but the upper beds and the Carboniferous Limestone hold to a constant strike of W. 15°–20° S. The principal faults, as before, follow the strike, but some few cut across it approximately at right angles. The lower limit of the Silurian outcrop, which we believe to be a fault throughout Sheet 230, is visible at Arbont, near Middleton Hall. Mr. Thomas

A big fault associated with a crush-conglomerate makes itself evident near Aberglasney in the parish of Llangathen. Passing the farm called Grongar East, it cuts through the hill (Grongar) and probably proceeds to the north of Dryslwyn Castle, where Llandilo Flags and limestones are faulted against higher shales. What is evidently the same disturbance is indicated near Llangathen by De la Beche and Ramsay on Horizon Section, Sheet iii, Sect. No. 2. It is interesting to note that this line of crush runs more or less parallel with the western part of the curve in the strike of the Silurian rocks described above.

The rocks to the west of Llanarthney are much folded. In a series of anticlines and synclines, each anticline presents a steep dip to the south and a gentle dip to the north. The steep side, there is reason to think, is often replaced by a fault or thrust bringing up older rocks, but the unravelling of the detailed structure must wait the examination of the country further west.

The configuration of the ground in the middle of the outcrop of the Old Red Sandstone north-west of Carmel led to the anticipation that there must be here a disturbance of considerable magnitude. Among a number of strike-features a depression, formerly occupied by a *pysyodlyn* or fish-pond, at once attracted attention by its depth. Followed westwards it led to Bryn-yr-odin, where the existence of a great disturbance was obvious, for an outlier of Carboniferous Limestone occurred in what appeared to be a most anomalous position.

The structure presents a close similarity to that of Castell Cennen, where also a mass of limestone has been thrown in far below the main escarpment. The fact that the Old Red Sandstone between the outlier and the escarpment dips uniformly southwards at a high angle, makes it certain that the displacement by which the limestone was dropped in must have been enormous. The fracture is visible, and in part of its course, if not everywhere, is compound, for a strip of Old Red Sandstone is wedged in along it between two strips of limestone, while much of the limestone is in a more or less pulverised condition. The northern boundary of the outlier is also a fault. The limestone extends along the belt of disturbance for about a mile and a quarter only, but the depression which characterises the belt continues and leads us to Porth-y-rhyd, where again view may be obtained of the smashed strata to which the depression is due. Thence it ranges down the Gwendraeth-fach across a tract which has not yet been examined.

Mr. Strahan.

Near Llandyfaelog the Gwendraeth-fach enters the ground surveyed by Mr. Wilkinson, and was found in accordance with anticipation to follow the line of disturbance. A third outlier of limestone was detected here by Mr. Wilkinson, holding the same relative position to the main escarpment and to the Old Red Sandstone as those of Castell Cennen and Bryn-yr-odin. On its south side the limestone is certainly faulted, on its north side probably so, and the evidence for a huge displacement in the southern fault is no less conclusive than in the other cases. It is to be noted, however, that the Gwendraeth, after following the line of disturbance for some miles, leaves it just where the outlier of limestone commences, an unusual circumstance for which explanation will be sought. West of the outlier the course of the disturbance is indicated by a slight depression past Llandyfaelog, but a short distance further on it catches the local drainage and has been eroded into a deep ravine, which continues past Iscoed to the shore of the Carmarthen estuary. The bottom of the ravine shows marls and Brownstones in an intensely broken state.

On the same line, prolonged across the estuary, we get evidence of a disturbance at Llanstephan Castle, and finally a clear view of it on the west side of the Llanstephan promontory. Here the disturbance seems to have passed into a monocline without fracture. The marls with cornstones which form the southern part of the promontory roll down northwards at a high angle and pass out of sight. Higher beds of the Old Red Sandstone come in above, with a gradually decreasing dip, and eventually nearly horizontal Carboniferous Limestone appears in the top of the cliff at Black Rocks. A gentle anticline runs parallel to the disturbance, but a few hundred yards south of it, and some small overthrusting is well laid open to view in the cliff. One such fracture, 300 yards south of St. Anthony's Cottage, slopes gently southwards; the beds above the fracture have been pushed up a few feet northwards, relatively to the beds below.

The course of this disturbance along the middle of the outcrop of the Old Red Sandstone for so many miles, its effect in throwing in patches of limestone by what must be an enormous displacement, and lastly the guiding influence which it has exercised upon the rivers, in common with other disturbances of the E.N.E. and W.S.W. system, all combine to give it an unusual interest.

Continuing across the outcrops southwards from the disturbance last mentioned we reach the northernmost of the series of overthrusts which have been proved in working the anthracitic coals. The details are given on p. 184, but we may here recapitulate the main facts, that they run in a general E.N.E. and W.S.W. direction; that the fractures, though sometimes nearly vertical, all hade to the south and lastly that they have the effect of throwing the strata down northwards and of repeating the outcrops. Three stages in the formation of a complete overthrust can be recognised, namely, the simple monocline or roll down to the north, the monocline accompanied by inversion,

and lastly the overthrust, which may be regarded as a monocline in which folding has been supplemented or replaced by fracture and displacement. Mr. Strahan.

It is worthy of note that these and the Gwendraeth Valley disturbance differ from the folds in the old rocks near Llanarthney (p. 45), in the fact that they throw the strata down northwards. Those folds, on the other hand, may be regarded as a series of monoclines by each of which the strata are rolled down southwards. An explanation may be found in the fact that the two sets of disturbances lie on opposite sides of a great anticline.

The tracing of these lines of disturbance through the Pennant region has proved a matter of great difficulty, but one at least is clearly indicated near Llannon (p. 184), and what may be the same passes south of Horeb into country not yet examined. Here again the fracture-plane slopes to the south, and the rock above it has been pushed northwards relatively to that below.

The Llanelly syncline runs almost due east and west, and both in this fact and in position is linked rather with the pre-Triassic system of South Carmarthenshire and Glamorganshire than with the E.N.E. system which commences in the Vale of Neath. The structure, as shown by the section forming Fig. 2, includes an overthrust, which "dips" southwards, like those described above.

In the limestone of Gower small overthrusts are far from uncommon. One which runs E.S.E. just below the entrance to Mitchin Hole, traverses limestone which dips south, and hades in the same direction, but at a slightly steeper angle than the beds. It is particularly interesting to find that a N.N.W. fault, to which the cave and the gully leading to it owe their existence, shifts the thrust-plane. Another which occurs 500 yards east of Black Grit contains a "spar," which testifies to the energy of the movement even in these subsidiary fractures. A specimen of the "spar" is thus described by Dr. Flett:—

E. 3626. Mylonised limestone. A grey or pinkish-grey, thin-banded platy limestone cut by numerous small veins which run in a direction almost perpendicular to the lamination.

The microscope shows that the rock has been crushed and drawn out to such an extent that the original structure has vanished, and a fine calcareous powder has been produced arranged in slightly undulating, flattened, lenticular folia parallel to the direction of movement. The main foliation is crossed by an oblique minor banding, which is wavy and resembles the *Ausweichungsclivage* of many shales. There are *Augen* of uncrushed limestone, but many veins of granular calcite cut through the sheared mass, mostly perpendicular to the lamination, but sometimes parallel to it. They occasionally show slight traces of deformation, but as a whole are undoubtedly later than the shearing.

The finest exhibition of an overthrust, however, is to be found in the east side of Caswell Bay. The structure can be best determined by following the outcrop of a thick bed of light-coloured oolite. That rock crops out at the engine-house, and rises to the top of the east cliff close by. Beneath it we see in the foot of the cliff dark and thin-bedded limestones, including a thinner band of oolite, for about 130 yards, all dipping north,

Mr. Strahan. when we reach the overthrust. The fracture-plane hades to the north, and a slight burring of the broken edges of the beds above it proves that they have been pushed southwards up it. Beneath it we find the thick white oolite again, dipping south. Then follows a syncline, in which the oolite temporarily passes

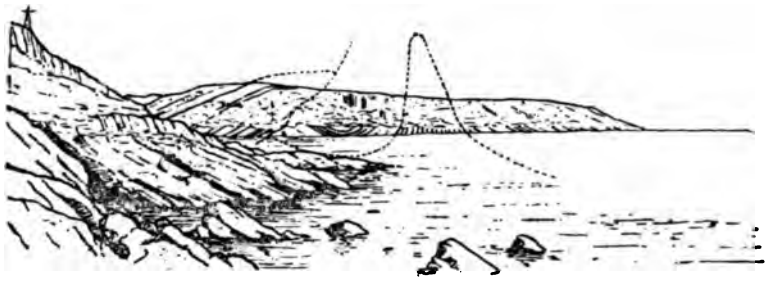

Fig. 2. *Overthrust in Caswell Bay.* (*From a photograph.*)
By A. STRAHAN.
(The dotted line indicates the base of the thick oolite referred to.)

beneath sea-level, and an extremely sharp anticline in which it temporarily passes above the top of the cliff. Here we reach beds with a uniform dip to the south. The structure, therefore, may be described as an anticline, with subsidiary folding, and with fracture and overthrusting. Perhaps because it is on the north side of an anticline, the thrust-plane slants northwards, and the beds have mounted from that side. The extent of the movement has probably amounted to 200 feet or more.

The relative age of this east and west system with the E.N.E. and W.S.W. system previously described still remains uncertain. That the east and west folds and fractures of the south are pre-Triassic is easily proved, but that the other system, which includes the Vale of Neath, Cribarth, Cennen, Gwendraeth Valley and other disturbances is of much later date, has been inferred partly from the fact that they directly determined the river-system, and partly from their relation to the N.N.W. system of normal faults. It was found that though the faults cut through all undoubtedly pre-Triassic structures, as for example, at Mitchin Hole, they generally failed to traverse the W.S.W. belts of disturbance, or in some cases appeared to be deflected by them. So far as the past year's work is concerned, not much further light is thrown on the subject. The Llanelly syncline is certainly cut through repeatedly, and would for other reasons have been assigned to the pre-Triassic set. But the Llannon disturbance, which ranges south-west, is believed by Mr. Dixon to be crossed similarly, while it is thought that some faults traverse the Cross Hands and Ammanford belt of disturbances. It should be noted however that the detailed structure of that region is not and never will be known, and that one of the principal N.N.W. faults which forms our best available explanation of what is visible on the surface, follows an unusually sinuous course, such as might have been caused by subsequent shifting.

Further light may be thrown on the relative ages of the two systems by an investigation of the anthracitisation of the coals now in progress (p. 189). There is reason to think that a connection between the W.S.W. system and the anthracitisation may be traced, whereas the N.N.W. faulting appears to have been subsequent to the anthracitisation. Mr. Strahan

PLEISTOCENE.

Raised Beach.

Two possible representatives of the Raised Beach have been found on the Carmarthen coast west of Gower. One occurs in the cliff east of Llanstephan Castle. Under 20 feet of Boulder Clay there lies a fine deep-red stratified loam with fine gravel composed chiefly of Old Red Sandstone detritus. The deposit is several feet thick and is but slightly above the present storm-beach. No shells occurred in it, and though it possibly represents the Raised Beach, it is at least as likely to be a stratified band in the Glacial Drift, like the gravel in Rhossili Bay described in the "Summary of Progress" for 1901, pp. 52, 53. The second example occurs immediately west of Ragwen Point at the western end of a small cliff of Boulder Clay. Concreted sand with small pebbles, and with blown sand, appears from beneath the Drift, just above high-water mark. No shells were observed. Mr. Wilkinson.

Glacial.

The glacial phenomena of the region surveyed during the past year are connected with two main ice-flows, the one of which travelled westwards down the Towy Valley, with a tendency to escape southwards wherever the form of the ground permitted, while the other spread southwards over the Coal Field to the coast near Llanelly and Pembrey, filling, probably to overflowing, the valleys of the Loughor, Gwili, Morlais, Lliedi and other rivers. Mr. Strahan.

In the Vale of Towy Mr. Thomas finds that the Boulder Clay on the Ordovician outcrops consists entirely of grits and shales derived from more northerly districts, while on the Old Red Sandstone two varieties occur, the one a blue clay full of large far-derived boulders, the other a bright-red till composed almost entirely of the local material. Much of the Boulder Clay becomes gravelly westwards. Mr. Thomas

The tendency of the ice to escape southwards is illustrated near Llanarthney where the Silurian escarpment breaks down. A valley trending S.S.W., and connecting the Vale of Towy with that of the Gwendraeth-fach, contains much Glacial gravel, brought down apparently by a part of the Towy ice-flow. As much as 40 to 60 feet of Boulder Clay can be seen in parts of the Gwendraeth-fach. Striæ on the Millstone Grit at Garn and other places point S. 22° W.

Boulder Clay has been distributed freely along the lower part of the valleys of the Towy, the Tâf, and their tributaries. Many of the boulders have been derived from the Old Red Sandstone, Mr. Wilkinson.

Mr. Wilkinson. but some coarse grits or conglomerates resemble the older beds which crop out to the north-east. The same direction of glaciation is suggested also by the large boulders, apparently of Millstone Grit, which abound north-east of Kidwelly. Much of the Boulder Clay is gravelly, but a distinct deposit, consisting of bedded sand and fine gravel occurs on the plateau north of Pendine.

Mr. Cantrill. Within the limits of the Coal Field a large sheet of Boulder Clay extending from Llandybie southwards contains Carboniferous Limestone, Old Red Sandstone, and older rocks, which have travelled apparently in a S.S.W. direction. Some gravelly mounds lie with their longer axes in the same direction.

Another large tract extends from Cross Hands south-eastwards. There the bulk of the material is of Coal Measure origin, but Old Red Sandstone and Silurian boulders also occur. Some thin disconnected patches in the Gwendraeth Valley west of Cross Hands include some boulders of Millstone Grit and Old Red Sandstone, the latter increasing northwards towards its source.

The conclusions as to the direction of transport are confirmed by some striæ near Foel Gastell which point S. 25° W.

Mr. Dixon. In his examination of the region lying around Llannon and Sylen Mr. Dixon finds that the bulk of the Drift is composed of local Coal Measure rocks, though Old Red Sandstone is always present, and concludes that the material has been derived from a northern source. On Mynydd Sylen at a height of 850 feet above the sea there is a red drift composed chiefly of Old Red Sandstone, though in the Gwendraeth Valley, nearer to the source and 600 feet lower down, the Drift contains but little of that rock, the explanation possibly being that the Gwendraeth ice-flow was crossed obliquely by a higher flow moving more nearly southwards.

Striæ have been noted near Llanedy and between the Morlais and Gwili all pointing south, and below Pont Morlais pointing S 25° W.

Mr. Strahan. In the maritime region the Drift is mostly a gravelly Boulder Clay with an occasional mound of clean gravel. The boulders, among a vast majority of Coal Measure rocks, always include many of Old Red Sandstone, brought down presumably from the North Crop; but by what route they travelled it is difficult to determine, inasmuch as they are more abundant than in some of the valleys two or three miles to the north. Sand and fine laminated clay was found under Boulder Clay in the new reservoir in the Lliedi, and small lenticular bands occur elsewhere. Several striated surfaces have been noted, the direction of the striæ varying slightly from south when influenced by the form of the ground.

The depth of Drift in the low-lying and alluvial tracts is not so great as might have been anticipated. The Great Morfa Pit, of which the section is given on p. 178, reaches the rock at about 41 feet below Ordnance Datum, passing through two peat-beds.

A trial-sinking at Mach-ynys showed nearly twice this thickness of superficial deposits:— Mr. Strahan.

Mach-ynys Pit and Boring.

	ft.	in.
Earth	4	0
Glacial Deposits:—		
Gravel	15	0
Blue clay and boulders	7	6
Sand and gravel	11	0
Quicksand	13	0
Conglomerate	1	3
Gravel mixed with cliff-quar and blue stone	7	6
Bottom of Pit. Section continued in boring:—		
Gravel mixed with oxide of iron	12	0
Soft muddy ground	2	0
Quicksand	10	0
Stiff blue clay	1	6
Hard gravel	2	8
Quicksand	33	10
Sandstone rock [? a boulder]	3	2
Quicksand	3	0
Rock		
	127	5*

Another boring, half a mile to the E.N.E. and 500 yards north of the Great Morfa Shaft, reached the rock at 140 feet depth, while a third boring by the side of the Great Western Railway, 800 yards further north again, reached the rock at 92 feet depth. In the Llanelly new dock the rock was reached at a depth of a few feet only below Ordnance Datum. It would seem, therefore, that there is a buried valley running under Mach-ynys, and thence in an E.N.E. direction. The shafts and borings referred to all commenced at about 20 to 25 feet above Ordnance Datum, from which it will be seen that the rock lies as much as 115 feet below that level at the deepest point proved.

One more section remains to be noted. The trial-shaft at Elliott's Metal Company's Works at Burry Port, of which the section is given on p. 182, reached the rock at 58 feet, or about 35 feet below Ordnance Datum, but Stanley's Pit, of which no details have been obtained, is said to have traversed 120 feet of "superficial stuff," probably all Glacial Drift, before reaching the rock. The rock-surface must therefore be about 60 feet below Ordnance Datum, though it is close to the foot of a bare sandstone hill.

A section proved at Craig-lon may be mentioned here as showing the occasional difficulty of identifying Glacial deposits. A shaft and slant put down at the foot of the hill to the Gyscwm Vein passed through 51 feet of stiff blue clay with stones, underlain by 12 feet of loose sand crowded with sea-shells of recent species. The sand occurred at Ordnance Datum, and obviously formed the marginal deposit of the great marsh-tract of the Gwendraeth Estuary. Subsequently it was buried by

* In the Summary of Progress for 1901, p. 52, this depth was erroneously given as 120 yards.

Mr. Strahan. what must have been a wash, or possibly a slip, from the steep hillside close by, which consists in the lower part of shale. The imitation of a boulder clay was close.

ECONOMIC GEOLOGY.

The Cenrhos Rock which lies between the Gyscwm and Cenrhos Veins is one of the thickest and hardest Pennant sandstones in this part of the Coal Field. It has been quarried at Cwm Capel for use in the Barry Docks and other places, and is now worked at Gyscwm. A hard and massive Pennant is quarried also at the lower end of the lower Lliedi reservoir. Flags have been got for use in Llanelly from fine fissile sandstone near Brondini. The Llandilo Limestone is employed in districts near its outcrop. It is seldom dressed, being worked in flat slabs. The Carboniferous Limestone supplies much rough stone, while locally building material is got from the top of the Brownstones, from the green beds of the Senni Series and from the green beds at the base of the Old Red Sandstone.

Road-metal is got from hard quartz-grits which crop out in the Pennant at Fforest and Gwal-y-hwch. Llandilo Limestone is used locally on bye-roads, but Carboniferous Limestone for main roads. Bricks for building and engineering purposes have been made from the clays above the Gyscwm Vein and fire-bricks from the underclay of that vein. The Clay Vein was worked for the sake of its clay. The underclay of a small seam at Brondini, referred to on p. 189, and the shales above the seam have been used for the same purpose. The Carboniferous Limestone is quarried on a large scale at Honey-cors west of Laugharne, for burning and road-metal.

"Plastic clay" has been worked near Careg Gwenlas and Garn (see also p. 43) and the Millstone Grit, when it is sufficiently pure and not too hard, is worked for "silica sand." Much rotten grit occurs near Llyn-llech-owen, north of Gors-Lâs.

A lead-vein was worked some twenty-five or thirty years ago at Llandilo-rhwnws near Nant-garedig, in a rock of which the age is probably Tremadoc. The ore occurred as galena and appears to have been associated with blende and barytes. The vein seems to have ranged approximately north and south along a broken fold.

Lead-ore is still worked at Allt-Cystanog. A large mine, known as the "Vale of Towy," on the south side of the river near Carmarthen, yielded much galena. The vein, so far as can be judged from the waste-heaps, consisted of galena associated with vein-quartz, barytes and blende, with small quantities of copper-pyrites. The galena contained enough silver to pay for extraction. The vein probably ranges under the Towy to the neighbourhood of Abergwili.

Springs and shallow wells form the sources of water-supply for a large part of the area. Springs occur near the base of the Old Red Sandstone and at many other horizons in that formation, especially in the upper part where the dip is comparatively gentle. They issue also at the base of the Carboniferous Limestone.

Carmarthen, till recently, obtained its water from two wells sunk in the alluvium of the Towy. The supply is now got from the Ordovician country to the north.

Llanelly is supplied from a reservoir in the Lliedi Valley in which the surface-water is stored. A second reservoir higher up the same valley has recently been completed. The water is supplied without filtration. For the villages the impounding of springs in the neighbourhood has usually sufficed.

II.—Petrographical Work.

Dr. J. S. Flett.

During the year 1902 the rooms assigned to this department have been vacated owing to structural alterations in the Museum. New and improved accommodation has been provided and all the collections of sliced rocks and rock sections have been removed to their new quarters. The rock specimens exhibited in the museum have also been transferred to the gallery which was formerly occupied by the collection of pottery. The large amount of extra work entailed by these changes has been overtaken by Dr. Flett and Mr. John Rhodes and has necessarily to some extent interfered with the ordinary duties of the department.

The material sent in for microscopic examination has been contributed by every district which is being mapped in England and by all the field officers in Scotland. It includes an immense variety of rock types, many of which are of considerable scientific interest, and it would be impossible in this Report to discuss the important questions which they raise. A few of the more salient points, however, may be briefly considered.

THE GREEN BEDS OF THE SOUTHERN HIGHLANDS OF SCOTLAND.

The presence, among the altered sedimentary rocks of this region, of hornblende-schists, presumably of sedimentary origin, has been recorded in the "Summary of Progress" of previous years. They extend from Cowal to Aberdeenshire, and, as mapped out by the field officers, have, on the whole, a well-marked and continuous outcrop; but in the different districts they vary greatly in their characters, so that the green beds of Cowal and southern Argyllshire are in many ways unlike those of Perthshire and Aberdeenshire. Those of Cowal have been described in the memoir on that area, and are mostly chloritic and micaceous schists, which contain a variable amount of quartz, and sometimes epidote and albite. In them hornblende does not occur, or, at any rate, is very scarce, and this is also the case in the Loch Lomond area to the east of Cowal, where the green beds are mostly chloritic and epidotic grits, though, in the north part of that sheet (38 Scot.) hornblende begins to appear. But, as the outcrop is traced in a north-easterly direction through Perthshire, hornblende rapidly increases in abundance, and becomes, in fact, the characteristic mineral in this group of

Dr. Flett

rocks. In the neighbourhood of Aberfeldy Mr. Cunningham Craig* has mapped out a set of green beds, which, while undoubtedly of sedimentary origin, exhibit many of the features which are found in igneous hornblende-schists. Yet the clastic nature of the rocks can, in most cases, be definitely established, as, in the exposures a little south of Aberfeldy, pebbly quartz grains can be traced in lines along the face of the rock, which can only be regarded as clastic fragments disposed along the bedding planes. On the north side of the Tay similar rocks outcrop, but there the pebbly character is much less pronounced, and they are represented by fine, well-foliated hornblende-schists which simulate, with extraordinary perfection, the finer grained types of intrusive hornblende-schist of the region in question.

A microscopic study of sections of these green beds proves that they are hornblende-schists, mostly fine-grained, with small, water-clear crystals of felspar, and occasionally dark brown flakes of biotite. Many of them contain idiomorphic garnets of a wine-red colour. The various stages in the disappearance of the quartz grains are most interesting, and are perfectly exemplified in the slices prepared for Mr. Cunningham Craig. At first the pebbles begin to break down at their margins, and gradually the process of granulitisation spreads inwards through the grains till they become a fine mosaic of quartz, which is permeated by needles of green hornblende, which have spread inwards from the surrounding matrix. Finally the quartz grains disappear, and are indistinguishably blended with the mass of the rock, in which they form small, irregularly lenticular patches parallel to the foliation, or are altogether lost.

THE SCHIEHALLION BOULDER BED.

Among the schists of the southern Highlands, as has been mentioned in more than one of the Summaries of Progress, there are certain sheared conglomerates, or "conglomerate gneisses," in which occur pebbles of rock, still older than the surrounding schists. These have been involved in the earth movements which have affected the whole district, and they, as well as the matrix in which they lie, have undergone shearing, attended by recrystallisation. But in the Schiehallion district of Perthshire a boulder bed has been mapped by Mr. J. S. Grant Wilson, which is still not so greatly modified as to render it difficult to recognise the original character of its ingredients. A great variety of pebbles is to be found in this bed, most of them schists and gneisses, which prove the existence of a metamorphic terrane in this region before the "Dalradian" schists were deposited as sub-aqueous sediments.

Among these are others which are of interest to the petrologist, from their rarity as rock types. Very fine examples of scapolite-amphibolites (dark-coloured rocks consisting of scapolite

* Summary of Progress for 1901, p. 167.

and hornblende), and scapolite-hornblende gneisses (which contain scapolite, felspar, hornblende, and quartz) are to be met with, and there are also granites which are so rich in microcline and other alkali felspars, that they may be placed in the group of "alkali granites." The matrix is a sandy and argillaceous material, which, with advancing metamorphism, becomes a fine-grained biotite gneiss or granulite, and, where the changes have been least profound, the original characters of the pebbles are still perfect, but, as shearing progresses, cataclastic structures make their appearance, and become more and more conspicuous. Dr Flett.

THE MOINE SCHISTS OF SUTHERLANDSHIRE.

A group of rocks from this series in the vicinity of Aultnacallagach has been sent in by Mr. B. N. Peach in order to elucidate the changes undergone by both sediments and igneous rocks in this region. From an examination of these it is clear that, above the Moine thrust plane, there is in this place a band of rocks which have undergone intense shearing, though at the same time the original clastic structures of the sediments are still traceable in some of the specimens, and the dykes of porphyrite have not lost their typically igneous characters. Every stage of granulitisation down to complete mylonisation can be exemplified, and, from a comparative study of the specimens the original nature of the rocks can be perfectly established. Before the movements along the Moine thrust began, they were in all probability little modified types of sedimentary and crystalline igneous rocks, and, if the dykes belong to the post-Cambrian series of intrusions, (as there seems much reason to believe) it is clear that some part at least of the Moine schists of Sutherlandshire were still in the condition of ordinary sedimentary rocks at the close of Cambrian time.

THE RECENT ERUPTIONS IN THE WEST INDIES.

The disastrous calamity which overtook the British Colony of St. Vincent in May 1902, though less terrible in its consequences than the destruction of St. Pierre, awakened wide-spread sympathy in the mother country, and the remarkable circumstances with which it was attended, led the Royal Society of London, on the suggestion of the Colonial Office, to send out a scientific commission to report on the facts. Dr. Flett was chosen as one of the members of this commission and, with the permission of the Board of Education, he proceeded to the scene of the eruptions along with Dr. Tempest Anderson. The preliminary report of this commission was published shortly after their return to Great Britain and contains an outline of the history of the catastrophe and of the geological observations which they made during their visit to the West Indies. A fuller report has since been published by the Royal Society.*

Phil. Trans. Series A, vol. cc., pp. 353-553, 1903.

III. Chemical Work.

Dr. W. Pollard.

In the "Summary of Progress" of 1899 (p. 185) Phosphatic nodules from the Torridon Sandstone were mentioned. One of these has since been analysed (8760) also a Phosphatic nodule from the Carboniferous Limestone of Westmorland, the result of these analyses are appended.

Mr. Teall gave the following description of (8760):

"Cailleach Head, Loch Broom.

"Dark compact shale containing two black lenticles (1 × 1 × ¼ in.) The shale is composed of minute grains of quartz and felspar (.05 m.m. or less) and two micas. Epidote grains are fairly abundant. The transverse section shows that the rock is distinctly laminated, some layers being composed almost entirely of quartz, felspar, and epidote; others contain the two micas in abundance associated.

"The lenticles consist of the finer portions of the sedimentary material, especially micas, cemented with brown amorphous phosphate. They contain also minute black spherical bodies, brown fibres, or black or brown shreds, some of which show a distinct cellular structure. The cells measure about .01 m.m. in diameter, and are clustered in groups. The natural form is spherical, but this is sometimes interfered with by mutual pressure so that the cells have polygonal outlines. In such cases the fragments resemble portions of the parenchymatous tissue of plants, except as regards size. The black spheres show no structure where they are wholly immersed in the phosphatic matter; but when, as happens at least in one case, about half has been removed in the process of making the section, they are then seen to have been hollow and apparently perforated. The spheres vary from about .005 to .035 m.m. in diameter.

"The brown fibres are about .004 m.m. in breadth and of lengths varying from a few hundredths to tenths of a millimetre. They may be straight, curved, or even looped.

"That these various bodies represent organisms is highly probable; but the nature of the organisms is doubtful.

"The planes of lamination can be followed into the nodules, but they are more widely separated in the nodule than in the matrix, and the external planes of lamination curve inwards at the edges of the nodules. These facts appear to indicate that the concentration of phosphatic matter took place during, or immediately after, the deposition of the sediment.

A similar concentration of phosphatic matter has taken place sedimentary rocks of many different geological periods, but in most cases the loose deposit in which the action occurred has been winnowed away by a process of contemporaneous erosion; so that the nodules are not as a rule embedded in their original matrix, as they are in this case.

The nodule from the Carboniferous Limestone, Westmorland, was collected by Mr. J. Rhodes, and described in a paper entitled "Notes on the occurrence of Phosphatic Nodules and Phosphate-Bearing Rock in the Upper Carboniferous Limestone (Yoredale) Series of the West Riding of Yorkshire and Westmorland Border." *

ANALYSIS OF PHOSPHATIC NODULES.

I. Slice No. 8760. Cailleach Head, Loch Broom, Ross-shire. "Uppermost Beds of Torridon." 101. 12. N.E.

II. Slice No. E. 3714. Farcote Gill, Wild Boar Fell, Westmorland. "3 in. Nodular Bed on Little Limestone Chert." 1" 40, 6" 36.

Rep. Brit. Assoc. for 1901, p. 655.

Dr. Pollard.

	I.		II.
Residue. Insol. Nitric Acid.		37·08	18·74
		Part sol. in Nitric Acid.	
SiO_2 - -	29·99	2·26	14·68
TiO_2 - -	·40	—	Trace?
Al_2O_3 - -	8·58	2·46	6·36
FeO - -	4·22	4·22	1·03
MnO - -	·35	—	·36
(CoNi)O - -	·12	—	·15
CaO - -	26·93	25·63	40·02
MgO - -	1·50	1·50	·55
K_2O - -	1·54	·46	1·25
Na_2O - -	·30	·10	·55
Li_2O - -	Trace	—	—
P_2O_5 - -	20·29	20·29	28·98
F - - -	1·15	—	1·55
Organic Matter	1·48	—	1·46
CO_2 - - -	1·96	—	} 4·08
H_2O at 105°	·48	—	
H_2O above 105°	1·55	—	
Total.	100·84		101·02
Less O for F.	·48		·65
	100·36		100·37

NEPHELINE.

Nepheline separated from Nepheline-Aegirine-Syenite-Pegmatite. (9322.) A boulder from Coulmore, Ross-shire. 1″ 101.

Separated by Bromoform diluted with Xylene.

Sp. gr. between 2·60-2·68.

	%	Molecular ratios	
SiO_2 - - -	44·87	·7429	
Al_2O_3 - -	32·00	·3131	
Fe_2O_3 - -	1·53	·0095	
CaO - - -	·47	·0084	
K_2O - - -	6·72	·0712	·2967
Na_2O - -	14·00	·2255	
H_2O 105° - -	·11	—	
H_2O above 105°	·87	·048	
Total	100·57		

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Theoretical composition for $3Na_2O$, K_2O, $4Al_2O_3$, $9SiO_2$.
($R_{15}Al_4Si_9O_{34}$ where $R = K:Na = 1:3$.)

SiO_2	44·0
Al_2O_3	33·2
K_2O	7·7
Na_2O	15.1
Total	100·0 (From Dana.)

An analysis of the felspathic constituent of this rock was made last year and will be found in *Summary of Progress*, 1901, p. 86.

White Mineral (alteration after Nepheline ?) from a vein east of Ault a Mhullin, east of Ault na Calla Gach.

		Mol. Rat.	
SiO_2	43·35	·7177	
Al_2O_3	31·93	·3124	
*Fe_2O_3	·78	·0049	
CaO	1·53	·0273	
MgO	·28	·0069	
K_2O	6·16	·0653	
Na_2O	8·03	·1293	·1996
Li_2O	·15	·0050	
CO_2	·57	·0130	
SO_3	1·67	·0209	
H_2O 105	·38	·0211	
H_2O above	5·47	·3036	
Total	100·30		

MnO trace. Cl, F, not found.

CLAY.

Analysis of Clay from Waterloo Brickfield, Reading. (Messrs. Poulton & Sons).

Mottled Clay of Reading Beds. Collected by H. W. Monckton, October 8th, 1902.

SiO_2	53·43
TiO_2	·84
Al_2O_3	18·77
Fe_2O_3	9·42
CaO	·51
MgO	1·40
K_2O	3·39
Na_2O	·54
H_2O at 103°	5·55
H_2O above 103°	6·59
Total	100·44

Trace of Li_2O, MnO.

FeO cannot be estimated with any certainty owing to the presence of a little organic matter ; all iron calculated as Fe_2O_3.

	Per cent.
Sand	21·9
Silica (combined)	31·6
	53·5

* State of oxidation not determined.

MOTTLED LIMESTONE.

The following Analysis of a specimen taken from a quarry on the road between Oxwich and Oxwich Castle, Gower, Glam. was made to prove that the cause of the "mottled" appearance of one of the beds of the Carboniferous Limestone in Gower was due to dolomitisation. In thin section the light part (dolomite), is seen to be crystalline and devoid of organic structure, whilst the darker portion (mostly limestone) shows organic structure distinctly. Here and there in the dark part rhombs of dolomite can be observed. The dark and light portions were separated by picking out (it was impossible to get a clean separation), and analysed with the following results :— Dr. Pollard.

	Light.	Dark.
Part insoluble hot dil. Hydrochloric, dried at 105°	5·85	2.42
Water at 105°	·21	.06
Oxide of iron, etc.	·63	.25
Lime	34·17	50.98
Magnesia	15·29	3 21
Carbonic acid	43·60	43·62
TOTAL	99·75	100·54

Ratio of lime to magnesia to carbonic acid :—

Light	-	-	1·61	-	-	1	-	2·62
Dark	-	-	11·47	-	-	1	-	12·46

The above figures clearly show that the light part is dolomite with some limestone, whilst the dark is almost entirely limestone.

LAUMONTITE.

Mineral occuring with granite from the Baveno Granite Quarries. (Presented by Mr. Hamilton Gunn.)

		Mol. Rat.
Silica.	51·35	·8501
Alumina.	22.14	·2166
Ferric Oxide.	·67	·0042
Lime.	12·35	·2205
Water.	13·65	·7575
Total	100·16	

(At 105° 1·78% of the water is driven off, 1·25% between 105° and 200°.)

This gives the ratio,

Silica to Alumina, to Lime, to Water :—

3·92 1 1·01 3.49

Laumontite is :—

4 1 1 4

There can be no doubt that this is that mineral, with some of the water lost.

BARYTO-CELESTITE.

Dr. Pollard. Partial Analysis of Baryto-celestite from Chipping Sodbury railway-cutting.

Specimen sent by Mr. W. H. Wickes, Bristol.

BaO	24·48
SrO	31·89
CaO	1·22
SO_3	39·03
*Fe_2O_3	1·26
Loss on Ignition	1·81
Total	99·69

VOLCANIC ASH.

Analysis of pumice separated from Volcanic Ash which fell in Barbados on May 7–8th, 1902. Sp. Gr. below 2·44.

SiO_2	59·97
TiO_2	·72
Al_2O_3	18·13
Fe_2O_3	2·28
FeO	3·95
MnO	Trace
CaO	6·62
MgO	2·44
K_2O	1·09
Na_2O	4·11
H_2O	·48
P_2O_5	·21
(CoNi)O	Trace
Total	100·00

CHROMIUM AND VANADIUM IN BASIC ROCKS.

A short time ago Sir Norman Lockyer examined spectroscopically a few basic rocks which had been analysed in this laboratory and noted the presence of vanadium and chromium in the majority. The fact that these constituents often occur in rocks has been known for some time, but it seemed worth while determining the quantities in a few specimens from Great Britain. Recently a large number of rocks from the United States have been thus examined in the laboratory of the United States Geological Survey and the analytical methods used described.† These methods have been followed in the examination of a few British rocks, and the values for Cr_2O_3 and V_2O_3 are given below—

	% Cr_2O_3	% V_2O_3
8062	·01	·06
8057	(·004)	·03
8043	·03	·03
8194	·02	·02
8185	·04	·04

* State of oxidation not determined.

† W. F. Hillebrand. Bull. U.S. Geol. Survey, No. 167, p. 49; No. 176, p. 82.

In [8057] Chromium was found spectroscopically first, otherwise it would hardly have been suspected, as the colouring was very weak. Naturally this figure must be regarded only as a rough approximation. Dr. Pollard.

Names and Localities of above rocks:—

8062. Loch a'Bhasteir, Skye. Dolerite. (Analysis "Summary," 1901, p. 87.)
8057. Brochbeinn, Skye. Olivine Basalt. (Analysis "Summary," 1899 p. 172.)
8043. Sligachan river, west bank, just below junction with Allt Coire Riabhaich. Olivine Gabbro. (Analysis "Summary," 1899, p. 172.)
8194. Coire a'Mhadaidh, Skye. Gabbro. (Analysis "Summary," 1899, p. 172.)
8185. Alltt Feionn Fharadid, Drynoch, Skye. Olivine Basalt (lava) (Analysis "Summary," 1899, p. 172.)

IV. Palæontological Work.

Upwards of 4000 specimens of fossils have been received and registered in the books of the department and the greater part determined specifically. Between three and four hundred of these fossils have been mounted and added to the collection exhibited in the Museum. Mr. E. T. Newton.

The nomenclature of the Rhætic and Jurassic Mollusca in the collection is being revised by Mr. H. A. Allen, and this work has occupied the greater part of his time during the year. He has now completed the revision of the Lamellibranchiata and Gasteropoda from the Rhætic, Lower, Middle and Upper Lias, and also the Gasteropoda of the Inferior Oolite It has been found convenient while prosecuting this task to make a list of the type and figured specimens. This important and useful piece of work has been carried out by Mr. Allen, and a catalogue of the type and figured Gasteropoda from the Rhætic to the Inferior Oolite inclusive is printed as an appendix to this Summary (see page 217). A similar revision of the nomenclature of the Eocene and Oligocene Vertebrata has been carried out by Mr. Newton, but the catalogue of the types was published as an appendix to the Summary for the year 1900.

The specific determination of the series of fossils, chiefly Jurassic, collected by Mr. C. B. Wedd and Mr. D. Tait in 1901, in the islands of Skye and Scalpay, has occupied a large part of Dr. F. L. Kitchin's time. The species determined from both marine and estuarine beds will doubtless in the near future be of much value in the correlation of the strata, but call for no special notice at the present time. Much interest attaches to the discovery of Cretaceous beds in Scalpay as shown by the presence of *Pecten asper*, a preliminary note on which appeared on page 145 of last year's Summary.

The determination of certain species among fossils from Lower Palæozoic beds in South Wales collected by Mr. T. C. Cantrill and Mr. H. H. Thomas has been of value in settling definite horizons in that district. Mr. J. Pringle has been

. E. T. wton.

occupied in collecting Carboniferous fossils in South Wales and was for part of the time accompanied by Mr. J. Rhodes. The chief object of this collecting was to obtain a large series of Coal Plants from definite horizons in order to assist Mr. R. Kidston in the Palæobotanical work on the district, which he has been good enough to undertake for the Survey. Besides these fossil plants which are now being worked out by Mr. Kidston, and a series of mollusca, Mr. Pringle was fortunate enough to obtain some examples of those rare fossils Limuloids and Arachnids, *Prestwichia* and *Eophrynus*, as well as a Myriapod and some insect wings. The invertebrata of this collection have been determined by Dr. Kitchin.

On two occasions Mr. Newton visited Derbyshire to examine the cave which had been discovered at Longcliff, and for the purpose of studying the mammalian remains that had been unearthed. The cave has since been explored by Mr. Arnold Bemrose, under the auspices of the Derby Antiquarian Society, and Mr. Newton has been able to arrange that a series of the remains be reserved for this Museum.

We are under obligation to several gentlemen who have been kind enough to lend specimens for Survey purposes. Mr. J. de W. Hinch sent a series of glacial shells from County Dublin at Mr. Lamplugh's request. Mr. W. Whitaker placed at our disposal a number of fragmentary shells, representing fifteen species from a well boring at Lowestoft, which showed the existence of Norwich Crag at a depth between 138 and 181 feet. At Mr. T. I. Pocock's desire Messrs W. Hunter and R. E. Middleton, engineers for the Staines Reservoirs, were good enough to lend us certain specimens obtained from the Thames Alluvium, near Staines, among which Mr. Newton recognised the Antlers and other parts of an Elk (*Alces machlis*). Although this species has been several times met with in the north of England and Scotland, it has only once before been found so far south as the Thames and that was at Walthamstow, in Essex; Sir R. Owen, in 1869, having determined some limb bones from that locality. In the present instance the skull with both antlers, as well as the lower jaw with perfect teeth, and a tibia, supply much more satisfactory evidence that the Elk extended so far south as the Thames. A full account of this specimen has been published by the Geological Society, and while these pages have been passing through the press, the Joint Committee of the Staines Reservoirs, at the suggestion of the engineers, have courteously presented the remains to this Institution, where they may be seen exhibited in the Museum.* (See also p. 207.)

Mr. Ll. Treacher has kindly lent us a number of Eocene fossils collected by himself at Wokingham and Sonning, which has enabled us to add to Mr. Blake's Memoir on the Geology of Reading a good list from the top beds of the London Clay, at the former locality, and to verify many of the species recorded by Prestwich from Sonning. Mr. George Morris has lent us some

* *Quart. Journ. Geol. Soc.*, vol. lix p. 80.

Lower Cretaceous fossils from the Snettisham Clay of Heacham; and Mr. Neilson a few Rhætic specimens from Arran. Mr. E. T. Newton.

Mr. Howard Fox and Mr. W. Barratt have presented to the Survey a series of interesting but obscure fossils found in the Devonian Shales near Newquay, from which neighbourhood Mr. Clement Reid has also made a collection.

The necessity for an easy mode of reference to the localities from which fossils have been collected has led to the preparation of a card catalogue..

The correction in proof of the palæontological portions of various Memoirs passing through the press has demanded a large amount of time, and this has been especially the case with the Memoir on the "Cretaceous Rocks of Britain" by Mr. A. J. Jukes-Browne, since it has been necessary to verify several of the lists of fossils as well as to revise much of the nomenclature.

Our thanks are due to several donors of fossils, and a detailed account of their presentations will be found among the list of donations to the Museum published in the Annual Report of the Survey.

The collection of fossils continues to be much used by workers in Palæontology and part of the officers' time has been occupied in assisting, as far as might be possible, such workers in their studies, and also in answering the numerous enquiries relative to fossils.

The following is a list of the specimens in the Museum which have been figured during the year:—

In the PALÆONTOGRAPHICAL SOCIETY, Vol. lvi, 1902.

By Miss E. M. Wood and Miss G. L. Ellis:—

Dichograptus octobrachiatus (*Hall*).
Dichograptus octobrachiatus (*Hall*) var. Sedgwicki, *Salter*.
Bryograptus Kjerulfi, Lapworth

By Mr. Hy. Woods.

Pecten orbicularis, *Sow.* var. haldonensis, *Woods*.
—— curvatus, *Gein.*
—— subacutus, *Lam.*
—— Robinaldinus, *d'Orb.* (2 specimens.)
—— arlesiensis, *Woods*
—— pulchellus, *Nilss.*

In the QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY Vol. lviii, 1902. By Mr. C. A. Matley.

Obolella (?) Salteri, *Holl* (2 specimens.)
Linnarssonia Belti, *Dav.*

By Miss J. Donald.

Murchisonia (?) dudleyensis, *Donald*
Cyrtostropha bicincta, *M'Coy*
—— obscura, *Portl.*
Lophospira (?) angulocincta, *Salt.*

V. MUSEUM OF PRACTICAL GEOLOGY.

The Geological Museum.

Mr. J. A. Howe.

During the year the Museum has benefitted by an important donation, presented by Col. Waldo-Sibthorpe. This is a collection of nearly 400 specimens, mostly of polished chalcedonies and agates but comprising also a number of precious stones, cut and in the rough state. Especially noteworthy is a very fine diamond in the matrix.

A small collection of about 60 specimens illustrating the ores of Greece has been presented by the Foreign Office and is now on exhibition.

Messrs E. Davis and Co. have presented some very large plates of Mica from India.

Among the specimens acquired by purchase may be mentioned a series of Calcite, Fluorite, Barytes, Quartz, Zinc Blende and other minerals from the North of England.

The Library.

A number of useful additions, the majority by purchase, have been made during the year.

The work of constructing a card catalogue of the contents has been commenced and is now rapidly nearing completion.

All the Geological Survey Maps accessible to the public have been handed over to the Library; it is hoped that this arrangement will make for the increased convenience of enquirers.

II. SCOTLAND.

Dr. J. Horne.

The ground surveyed in the Highlands was arranged in four districts, as follows:—

1. Knapdale and Lorne, Argyllshire, northwards to Loch Shiel, under Dr. Peach, F.R.S.
2. Central and Eastern Ross with parts of Inverness-shire and Sutherland, under Mr. Gunn.
3. Forest of Gaick, Atholl Forest and Glen Truim, under Dr. Horne, F.R.S.
4. The Islands of Rum and Eigg, under Dr. Peach, F.R.S.

The revision of the Carboniferous areas in Scotland having been sanctioned by the Board, the ground to be revised was arranged in two districts.

A. Midlothian with parts of West and East Lothian and Peeblesshire, under Dr. Peach, F.R.S.

B. District from Prestonpans to Cockburnspath and southwards to the Lammermuirs, under Mr. Clough, M.A.

In the district extending from Knapdale and Lorne in Argyllshire north to Loch Shiel, field-work was carried on in two subareas (1) in Sheet 36 which was completed; (2) in Sheet 53 on the north side of Loch Linnhe. The small unsurveyed area in Sheet 45 was finished and geological boundary lines were

traced for short distances into Sheets 28, 44, 52 and 62. The Memoirs on Sheets 37 and 45 (Argyllshire) are nearly completed, and an effort will be made to publish them simultaneously with these sheets. Dr. J. Horne.

In the district of Central and Eastern Ross, with parts of Inverness-shire and Sutherland, the areas surveyed lay chiefly in Sheets 93 and 83. Upwards of 25 square miles still remain to be completed in Sheet 83. Small tracts were also mapped in Sheets 102 and 73.

In the Eastern Highlands the remaining unsurveyed portions of Sheet 64, extending from the Forest of Atholl north by Gaick Forest and Glen Truim to Newtonmore were mapped. Boundary lines were also traced for a short distance into Sheets 63 and 74. The Memoir descriptive of Lower Strathspey (Sheet 85) was published last year and the Memoir on the country round Pitlochry (Sheet 55) is in preparation.

In the district of Rum and Eigg, considerable progress has been made with the mapping of these islands

The Memoir on the Tertiary Igneous Rocks of Skye has been completed and is ready for publication; and the Memoir on North Arran, South Bute, the Cumbraes, parts of the coasts of Ayrshire and Kintyre is in paged proof.

The revision of the Carboniferous areas of the Lothians was begun in October and continued till December; considerable progress having been made with the work during that period. The coast section from Cockburnspath to Dunbar, which shows an excellent section of Lower Carboniferous rocks, was re-examined with the view of comparing the latter with their equivalents along the Scottish border and in Midlothian. The limestones underlying the Edge coals have been traced along the east and south-east side of Midlothian basin. Additional information has been obtained regarding the oil-shale fields west of Edinburgh, and the volcanic rocks of the Pentland Hills, Arthur's Seat and the Calton Hills were re-examined.

The Memoir on the Geology of East Fife, embracing the great development of Carboniferous Rocks extending from St. Andrews to Leven and Buckhaven, was published last year.

I.—FIELD WORK.

1. Argyllshire—Knapdale, Lorne, and Northwards to Loch Sheil.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. J. S. Grant Wilson.
Mr. H. Kynaston, B.A.
Dr. C. B. Crampton.
Mr. H. B. Muff, B.A.
Mr. E. B. Bailey, B.A.
} Geologists.

The geological formations entering into the structure of the district are the Highland Metamorphic rocks of sedimentary and igneous origin, Lower Old Red Sandstone and associated volcanic and intrusive rocks, Tertiary intrusive rocks, Glacial deposits, Raised beaches, Peat and Alluvium. Dr. Peach.

(*a*) *Crinan north to Kilmelfort with the adjacent islands (sheet 36).*

Dr. Peach.

Physical Features.—The area surveyed in Sheet 36 is part of the low tableland, now forming the West of Argyllshire, which has been carved into hill and valley by subsequent streams, at a time when the land stood at a higher level. It has been depressed at a later geological period, so that sea lochs and sounds now fill the lower parts of the valleys, while the promontories and numerous islands fringing the coast represent the ancient dividing ridges and hill tops. The whole region bears evidence of having been profoundly modified by glaciation, and the raised beaches and rock notches show that the land has undergone slight elevation at different times since the glacial period.

The topography of the region varies in accordance with the underlying rocks and their arrangement, so that each area has its own characteristic features.

Messrs. Peach, Crampton, Muff and Bailey.

The Crinan district embraces part of the region lying between the Crinan Canal and Loch Sween, which is an extension southwards of the low plateau described in last year's Summary of Progress (p. 126). In the present area the narrow rocky, trench-like valleys, containing many lochs, have offered great facilities to the engineers to construct dams for impounding the enormous volume of water required for the Crinan Canal. The capabilities of the area for this purpose, as well as for water supply and motor power, are by no means exhausted.

In the lower part of the promontory of Craignish, lying between Loch Melfort and Loch Craignish, the same parallel N.N.E. and S.S.W. ridges, due to folded sheets of epidiorite, are observable as in the Kilmartin area, but the ridges are mostly below the 500 feet level. In the upper part, lying between Loch Melfort and the Barbreck river, the ground suddenly rises into a flat plateau, part of which reaches a height of 900 feet. The highest elevation—Tom Soilleir (1,199 feet)—from which the streams radiate, is evidently due to the masses of granite by which the area is invaded. The whole country is well watered and divided into moderate-sized farms where sheep and cattle are reared. That the soil is suitable for the growth of trees is clearly shown by the plantations near Craignish Castle, Lunga, Barbreck, and other localities.

With the exception of a narrow selvage of schistose rocks near the shore, the whole of the area north of Loch Melfort is occupied by andesitic lavas of the Lorne Volcanic plateau, which give rise to the terraced escarpments and flat tops so characteristic of that formation. Here the tableland attains an average height of about 500 feet, though a large part reaches a still greater elevation, the culminating point being Cruach Nam Fearna, which is over 1,000 feet. This area is divided into large farms for rearing cattle and sheep. The country is well watered and admirably suited for the growth of timber.

The island of Scarba is a continuation north-eastwards of the ridge of Jura, being separated from it only by the stormy Gulf of Corryvreckan. It forms a low conical hill of almost bare quartzite rising to 1,470 feet, on the east side of which there is

a strip of black schist and limestone, affording moderately good pasture, and a coppice of natural brushwood. The island is entirely in deer forest, and the population consists of the game-keepers and their families. Some plantations of fir and larch show that these trees thrive in sheltered localities. Lunga is a continuation northwards of the ridge of Scarba, but at a lower elevation. It forms one sheep farm, with one house tenanted by the shepherd. All the other islands, with the exception of Belnahua, which has a considerable population due to the presence of a large slate quarry, and Fladda, which has a light-house, are mere holms, rocks, and skerries grazed by sheep and cattle during part of the year, but have no permanent inhabitants. Messrs. Peach, Kynaston, Muff and Bailey.

HIGHLAND METAMORPHIC ROCKS.

District embracing Knapdale, Lorne, Scarba, Lunga, etc.— The schistose rocks of sedimentary origin entering into the geological structure of this district are shown in the following table in descending order under local names:— Dr. Peach.

IV. Scarba, Jura and Islay quartzite group.
III. Degnish and Shuna Limestone.
II. Easdale Slates and Limestone.
I. Craignish Phyllites.

The schistose igneous rocks consist entirely of epidiorites and their modifications.

I.—Craignish Phyllites.

As the name implies, these rocks are most typically developed in the promontory of Craignish and extend north-eastwards into the high ground lying between the Barbreck River and Loch Melfort, where they are much invaded and altered by granite. On the north shore of Loch Melfort they form a narrow strip of land between that Loch and the Old Red Volcanic platform, and they likewise make up the greater part of the Island of Shuna. Messrs. Peach, Kynaston, Muff and Bailey.

Craignish.—The sedimentary schists in Craignish consist of green and grey silky phyllites with calcareous sandy bands. A well marked strain-slip cleavage in the phyllites is inclined at about 60° to the E.S.E., but the dip decreases to about 40° on the west coast. The isoclinal folding is well brought out by the sandy and calcarous bands and by the epidiorite sills, which show that there is a general dip of all the rocks to the E.S.E. Usually the folds are so much thrown over to the W.N.W. that the dip of the bedding is less than that of the cleavage and on the western shore the beds are often nearly flat. The calcareous bands are represented by a whitish horny rock, showing an appreciable amount of sericite. This alteration does not appear to be due to any local "contact action," but was found to be present all over the district west of the Barbreck River. The harder calcareous and quartzose bands have suffered much compression, each bed being contorted into a series of short, Mr. Muff.

Mr. Muff. tightly packed folds, which considerably increase its true thickness. Sometimes each fold has been separated off from the adjoining ones by the shearing movements which have taken place, and a structure is produced resembling a row of pebbles embedded in the phyllites.

The sills of epidiorite intruded into the phyllites are thinner than those associated with the schists on the east side of Loch Craignish, but, as in the latter district, a coarse-grained massive kind may be distinguished from a finer-grained well-cleaved schist. The phyllites are indurated to a distance of one or two feet from the junction with the epidiorite.

Messrs. Peach and Kynaston. In the region between Loch Melfort and the Barbreck River some of the calcareous bands are thick enough to have been wrought for lime, and there seems to be an increase in the thickness of some of the sandy layers, especially near the top of the series. South of Loch Melfort, the members of this series and the epidiorites furnish evidence of contact metamorphism. The impure calcareous bands become calc-silicate hornfels, and in the neighbourhood of the granite, diorite, and felsite bosses, with which the region is invaded, the phyllites and sandy beds become dark, hard, dense biotite-hornfels and the calc-silicates develop pyroxene, though the grade of metamorphism is never so pronounced as that round the Cruachan granite mass.

Near the Point of Degnish, the promontory on the north side of Loch Melfort, the phyllites disappear beneath the black slates and limestones of the Easdale slate group.

Messrs. Peach and Bailey. *Shuna.*—The Craignish phyllites form about two-thirds of the island of Shuna and are well exposed on its shores. The manner in which lines of sigmoidal fragments of calcareous rock, representing once continuous bands, have been isolated among silky phyllites by folding and strain-slip cleavage is admirably displayed.

On the shores of this island also, the ochreous weathered limestones and calcareous bands, as well as the sandy layers, are well displayed and constantly repeated by folding. Both on the N. and S. shores the junction of these rocks with the black slates of the Easdale series is well seen; the relation of the two groups being shown by the reappearance of the green and grey phyllites of this group on the crests of anticlines within the area occupied by the Easdale slates.

Although these areas are now separated from each other by sea, there can be no doubt that they form part of one great belt, in which these rocks are arranged in a compound anticline, throwing off the Easdale slates both to east and west. In fact they are seen to disappear beneath the slates to the north of the Barbreck River.

Over the whole area these rocks are more or less isoclinally folded, the dip of the axial planes and of the foliation being eastwards at high angles. In Craignish the longer axes of the folds lie nearly N.N.E. and S.S.W., while further to the west the direction gradually veers round, till, in Degnish and Shuna, it is nearly N. and S.

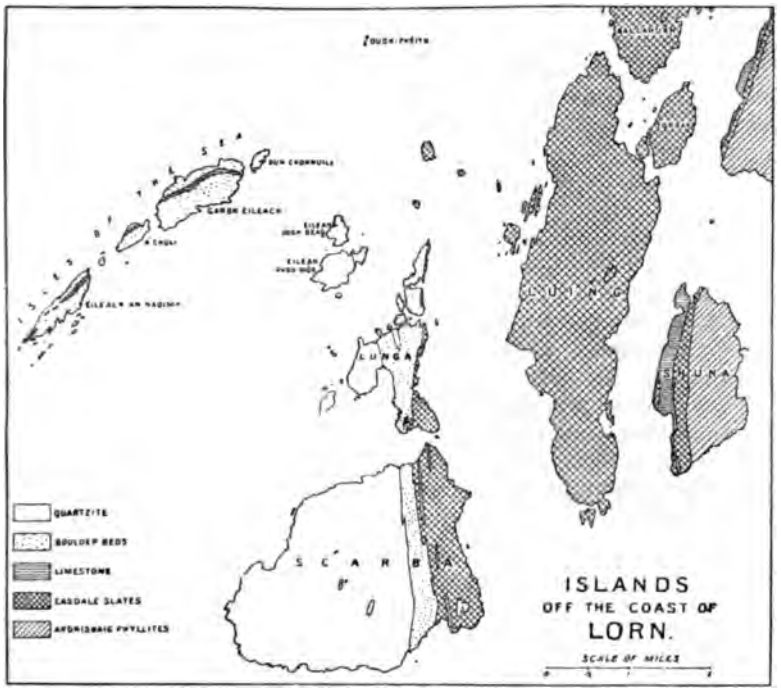

FIG. 3.

As to the horizon of the Craignish phyllite group, there can be no doubt that they are a reappearance of the Ardrishaig phyllites from beneath the great compound syncline, occupied by black schists, limestones, and quartzites, in the Kilmartin area referred to in last year's *Summary of Progress.* Messrs. Peach and Bailey.

II.—Easdale Slates and Limestones.

Degnish and Shuna.—As already stated, the passage from the Ardrishaig or Craignish phyllites into the black slates of this group is well seen in Degnish and on the shores of Shuna, where the latter consist of black and grey slates with a few intercalations of thin dark micaceous limestone and some white sandy layers; the series being highly folded. The black slates reappear in folds within the overlying limestones on Shuna, and in places make up its western shore line. The thickness of this group is evidently not great, though no reliable estimate can be given owing to the folding. Messrs. Peach and Bailey.

Luing and Torsay.—The strip of Easdale slates exposed in Degnish and Shuna is only the margin of a wide area of sea and land, floored with these rocks, for they reappear in the Islands of Torsay and Luing and in all the islets to the west in the Sound of Luing.

Messrs. Peach and Bailey.

Scarba and Lunga.—Still further west the Easdale slates form a belt of varying breadth along the eastern seaboard of the islands of Scarba and Lunga which is prolonged northwards into Eilean Dubh Mor and Ormsay. In all of these islands they are seen to disappear westwards under the quartzite and to rise on anticlines for a short distance within the eastern limits of these newer rocks.

The black slates are intercalated with lenticular sandy nodules and thin bands of quartzite, which in Scarba and Lunga attain a considerable thickness and sometimes include pebbles of blue quartz. All the rocks of this group are much folded, the strike of the beds and also of the cleavage being more or less N. and S.; while the dip of the cleavage is almost invariably to the E. at high angles. They form the eastern limb of a compound syncline which holds the overlying quartzites of Scarba and Lunga and is prolonged southwards into Jura. The belt is a continuation southwards of that of Easdale and Seil, and along the whole of this zone, workable black slates seem to be better developed than in any other part of the Central or Western Highlands.

Crinan Area.—The rocks throughout this area have been thrown into a series of sharp folds trending N.N.E. and S.S.W., so that the Easdale slates and associated limestones are exposed on the crests of anticlines by the denudation of the overlying quartzite. The largest area exposed stretches from the Crinan Canal across Dunardry southwards to the edge of Sheet 36 between Loch Fada and Loch na Brice, where the slates form a compound anticline of a highly complicated nature. Good roofing slates have been worked in two large quarries on Dunardry, and there are the remains of several smaller openings. The dip of the cleavage foliation is at high angles towards the W.N.W. Slates were also extensively quarried in another anticline of these rocks a little to the N.E. of Dunardry on the opposite side of the Canal near Cairnbaan.

Loch Sween.—Another anticlinal outcrop, along which these slates have been worked, stretches down Caol Scotnish, a branch of Loch Sween south of Crinan, where they are associated with thin dark limestone; and still other appearances of the black slates and limestones of this group occur in Glen Sabhail and on the extreme west coast.

III. Degnish and Shuna Limestone.

Messrs. Peach and Bailey.

On the west side of Degnish and Shuna the Easdale slates with their intercalated limestones are succeeded by a series of limestones which are dark blue, flaggy and micaceous, near the base, like those of the underlying group. These are overlaid by more massive bands of mottled limestone containing aggregates of black cleavable calcspar, set in a granular calcareous matrix, and alternating with flaggy limestone like the basement beds. Some of the layers, however, are grey and very siliceous and look

as if they had once been cherts which have been converted into crystalline silica and subsequently traversed by vein quartz. They are involved in the great series of isoclinal folds affecting the underlying Easdale slates and are foliated with the same set of cleavage planes. The limestones have been formerly extensively quarried on Degnish and in Shuna on the most northerly and westerly points. Messrs. Peach and Bailey.

Exposures of similar mottled limestones with black calcite have been observed at various localities in the Kilmartin district, where they are associated with dark limestone and the black schist of the Easdale group. The rocks here were overlaid by a limestone breccia with a more or less sandy matrix filled in with fragments of black schist, limestone and black calcite. The great amount of black calcite in more or less rounded grains, found in the pebbly limestones of the Kilmartin area, is doubtless due to the removal by denudation of a wide-spread area of the limestones of this group, prior to, or during the deposition of, the lowest members of the quartzite.

Isles of the Sea. In the extreme N.W. of the district in the Isles of the Sea—a group of rocky islets in the Firth of Lorne—thick masses of limestone and shale form the cores of anticlines, flanked by massive Boulder Beds—the lowest members of the quartzite series. These rocks being fine grained marbles, show signs of contact metamorphism, which affected them prior to their having been overlain by the boulder beds. They are doubtless a continuation to the south west of the limestones of Lismore, previously described by Mr. Muff,* and on the same horizon of those of Shuna and Degnish.

Evidence bearing on the nature of the surface on which the quartzite was laid down.

Additional evidence was obtained last season bearing on the unconformability and overlap of the quartzite, on the rock groups already described. In the Isles of the Sea, in the N. W. of the area, the Boulder Beds which there form the local base of the quartzite, are made up in great part of fragments of the underlying limestones, some of which measure eight feet across. To the S. E. in Lunga and Scarba, the local base of the quartzite is a Boulder Bed filled with fragments of the underlying Easdale slates, dark limestones and quartzites, some of the blocks of which are four feet long. The absence of the Shuna limestone from this area is probably due to its removal by denudation prior to the deposition of the quartzite. Near Old Poltalloch in the Kilmartin area Mr. Wilson found, as already stated, a small remnant of the Shuna limestone overlaid by a limestone breccia with fragments of black slate, black limestone and black calcite. In the same district a little further to the N. W. near the head of Loch Craignish, Mr. Muff found, during last season, the following evidence bearing on this unconformability. Messrs. Peach and Bailey.

* See Annual Summary for 1891, pp. 124, 125.

Mr. Muff. In two or three sections across the strike of the beds, anticlinal folds of the quartzite were noted within which a bed of black limestone appears; whilst the core of the fold is occupied by black slate. Between the black limestone and the quartzite there is occasionally a bed of pebbly limestone. This structure evidently points to a descending succession from quartzite, through pebbly limestone and black limestone to black slate. At least one syncline, exposed in cross section, shows a similar succession. About 400 yards N.E. of Loch Fearphuirn, pebbly grit about ten feet thick, with a thin sandy slate band at the base, rests on four feet of pebbly limestone containing blocks of black limestone. The pebbly limestone in turn rests on black limestone without pebbles, the even bedding of which is marked by numerous thin rather sandy layers. The pebbly limestone with a row of pebbles along its base cuts across the bedding of the black limestone in a manner strongly suggesting an unconformity. In the pebbly limestone 300 yards N. W. of Ormaig, boulders, up to two feet in length, of green phyllite, fine grained grit, hornfelsed limestone and felsite are found. No undoubted boulders of pebbly grit or epidiorite, which rocks are here folded with the limestone, were observed: but some of the blocks of green phyllite resemble the phyllites found in place in Craignish.

Messrs. Peach, Crampton and Bailey. Similar evidence was found in the area south of the Crinan Canal where, however, the Shuna limestone is absent, and where the pebbly limestone and pebbly quartzite—the lowest members of the quartzite—lie directly on the Easdale slates and black limestone. When traced to the S.E. corner of Sheet 36, the quartzite was found to rest directly upon Ardrishaig phyllites, with their characteristic rusty calcareous bands—a fact strongly suggestive of overlap.

Mr. Kynaston. Evidence to the same effect was obtained by Mr. Kynaston in the Loch Awe district, S.W. of Dalmally.

About four miles to the S.W. of Dalmally, and E.S.E. of Inistrynich, the quartzite is seen to rest upon grey phyllites with zones of greyish limestone, in an apparently unconformable manner. The base of the quartzite is here often very coarse and pebbly, and is full of fragments of decomposed limestone, closely resembling that of the underlying calcareous bands.

In the Kilchrenan area, an exposure of the Boulder Bed was examined on the shore of Loch Awe near the manse. It contains numerous boulders of a cleaved pale felsite, not unlike the boulders of felsite seen in the Boulder Bed of the Isles of the Sea. It is associated with a gritty band containing fragments of limestone, and with infolds of narrow bands of limestone and black slate. Boulders of grit are also seen in a dark matrix full of quartz grains. To the south of Achnamady, in the same district, the matrix of the Boulder Bed is in part gritty and in part bears a resemblance to the black slates, and is occasionally laminated. Some of the boulders of dark grey quartzite which it contains are very like the dark quartzite associated with the black slate, exposed in the burn below.

The quartzite on the north-west side of the Boulder Bed is often full of small fragments of black slate. Mr. Kynaston.

The Boulder Bed is again well seen in the small burn to the west of Kilchrenan, where it appears to rest upon the black slates, and its lower portion is full of fragments of black slate and fine grained quartzite.

The evidence, so far as it goes, appears to be in favour of an unconformity between the quartzite on the one hand, and the black slates and blue limestone on the other; the basement bed of the quartzite being represented by Boulder Bed, pebbly calcareous breccia, or pebbly quartzite.

IV. The Quartzite of Jura and Islay.

Representatives of this group were mapped in several parts of the district. They are most typically developed in the Island of Scarba where the excellent cliff sections display all the zones met with in Jura, which are here given in descending order. Messrs. Peach and Bailey.

5. Zone of flaggy, sandy, and calcareous shales, some of which contain matted and flattened worm-casts, the so-called "fucoids" of older palæontologists.
4. Zone of white and yellow fine-grained quartzite, with small rounded concretions, simulating "pipes" on weathered surfaces.
3. Zone of coarse, false-bedded, massive quartzites, with well-rounded pebbles of pink felspar and blue quartz.
2. Zone of flaggy quartzite with thin dark phyllitic partings, sandy flags and slates, sometimes with worm-casts ("fucoids") and occasional thin sandy dolomitic bands.
1. Zone of pebbly quartzite with blue quartz grains, passing locally into a coarse boulder bed full of fragments of black slate, black limestone, calcareous grit and quartzite, the largest blocks measuring 7 feet in diameter.

Zone 1 can be traced through Scarba, northwards through Lunga to Eilean Dubh Mor and Ormsay; preserving throughout much the same character as it bears on Scarba, and resting everywhere on the Easdale slates. Zones 2 and 3 are also found on Lunga and Eilean Dubh Mor, as well as on Guirasdeal and Eilean Dubh Beag. In Eilean Dubh Mor, however, the small pebbles in Zone 3 measure from two to three inches across, are well rounded and consist of rock fragments such as jasper, quartzite, hardened slate, felsite, and vein quartz, all of which are found in the Boulder Bed of the Isles of the Sea; but no granite pebbles were observed.

Zones 4 and 5 are only met with on the west coast of Scarba, where they are evidently the continuation northwards of the same bands found on the west side of Jura, and described in former issues of the *Summary of Progress*.

In all these islands the rocks are arranged in the same series of overfolds already described, the longer axes of which have a N. and S. trend on the eastern margin of the area; but towards the W., the direction gradually veers round till it becomes N.E. and S.W. On the west side of Scarba the dip of the strata and of the cleavage foliation is persistently to the eastwards.

Messrs. Peach and Bailey.

These rocks form part of the eastern limit of a great compound syncline, the other side of which is represented by the limestone core exposed in the Isles of the Sea. The grade of metamorphism is very low, the beds showing only a slight cleavage, and in the sandy shales of zones 2 and 5, which often split across their bedding planes, the original clastic micas are still plainly visible. The larger quartz grains of the quartzite show peripheral granulitization, while the finer grains are often entirely granulitized. There is more or less flaser structure and sericite is often found on the cleavage planes.

Messrs. Peach Kynaston and Bailey.

Isles of the Sea. In these islands the basement beds of the quartzite is made up of a tumultuous assortment of limestone fragments, many of them well rounded and upwards of eight feet in diameter. Further out from the limestone cores, and presumably higher up in the sequence, the blocks are smaller and the matrix becomes sandy and sometimes black from the presence of much black shale debris. Well rounded boulders, some of them two feet across, of rocks foreign to the island, such as granite, felsite, gneiss, schist, jasper, etc., are scattered through the beds or arranged in groups or nests along certain layers. In places, the beds become so free from included boulders, that they assume the appearance of sandy limestones, which sometimes attain a considerable thickness. These, again, are overlaid by massive sandy dolomitic beds charged with boulders of limestone and rocks foreign to that region. Up to this horizon, the rocks probably all represent zone No. 1 of Scarba; zone No. 2 is represented by sandy shales, bands of sandy dolomite and flaggy fine-grained quartzites, but occasional boulders, both of limestone and foreign rocks, occur throughout the series. This zone is followed outwards by alternations of massive sandy conglomerates, with boulders of limestone and foreign rocks, succeeded by false-bedded quartzites with occasional foreign boulders. These are seen both on the southern shores of the larger islands and in the small skerries that flank them, and probably represent part of zone No. 3 of Scarba. These rocks are arranged in a series of great isoclinal folds, with the long axes running E.N.E. and W.S.W.; the cores of which are occupied by the limestone. Some of the folds can be seen in cliff sections to the height of nearly 200 feet; the dip of the axes of the folds being to the S.S.E. The rocks are so slightly altered that they can hardly be regarded as schists. There can be little doubt that these rocks represent the Port Askaig conglomerate and possibly the Boulder Beds of Islay and of Schichallion in Perthshire. It is also highly probable that the limestone breccia, found by Mr. Muff on the north end of Lismore, invaded and metamorphosed by rocks of the type of the Cruachan massif,* is on the horizon of these basement boulder beds.

Mr. Bailey.

Crinan District.—One of the most important results of last season's work has been the successful correlation of the

* Summary of Progress for 1901, p. 125.

isolated strips of quartzite found on the mainland in the Crinan and Kilmartin districts, with the quartzites of Scarba, and consequently of Jura and Islay; a result due, mainly, to the work of Mr. E. B. Bailey. From the excellent sections exposed in the sea-cliffs extending south from Crinan he has proved that the pebbly basal quartzite is there overlain by a zone of flaggy quartzite with intercalations of silky phyllites, sandy and flaggy shales, sometimes with worm-casts (fucoids), and containing several bands of pebbly and sandy limestone; leaving no doubt that the rocks in this region represent zones No. 1 and 2 of Scarba. Mr. Peach and Dr. Crampton also traced these zones throughout the areas mapped by them. Mr. Bailey.

EPIDIORITE.

Epidiorite sills of the two types described in the Annual Summary for 1901, p. 120, occur throughout the greater part of the district occupied by the schistose rocks. South of the Crinan Canal they make up nearly half of the surface area, and they are extremely common in the Kilmartin district. They decrease in number in the Craignish and Loch Melfort areas, where, however, there are at least two sills on separate horizons; but they seem to die out westwards and disappear ere the western shores of Degnish and Shuna are reached. A little to the north-west of this line, at least one sill occurs in Torsay and passes a little way south into Luing; but no example was met with over the greater part of the latter island, nor in any of the islands to the west of it, surveyed during last season. Epidiorites, however, occur as well-marked dykes, filling fissures in Scarba and Lunga, in such a manner as to show that they had been injected after the quartzites had been folded and cleaved. While the epidiorite sills everywhere bear witness to having been folded and cleaved with the sediments into which they were intruded, the dykes which obliquely cross the bedding planes of the sediments are partly, or wholly, sheared parallel to their sides, and quite independently of the planes of schistosity affecting the quartzites. These dykes, therefore, although they may belong to the same great period of injection as the sills, must have welled into the fissure at a later date than the period of most intense plication, but while a certain amount of movement was still in progress. They are cut by the porphyrite and lamprophyre dykes, and by the Tertiary dolerites and basalts. The general direction of these dykes is north and south, but a few have a north-west and south-east trend. Most of them are a continuation northwards of those met with in Jura, and described in previous reports. Messrs. Peach, Wilson, Kynaston, Crampton, Muff and Bailey.

That the movements had not ceased at the time of the injection of the epidiorite dykes in Scarba is shown by the fact that these vertical structures are often abruptly truncated and shifted, sometimes to a distance of half a mile, by a series of thrust-planes which traverse the quartzite more or less parallel to its planes of schistosity, or in other words, to the axial planes Messrs. Peach and Bailey.

Messrs. Peach and Bailey.

of the isoclinal folds in which it is arranged. Sometimes several of these thrust-planes, each shifting the same dyke more than its own breadth, may be seen in a single cliff section. Flaser-structures and mylonization seem only to be set up along these planes, which were produced prior to the introduction of the Lower Old Red Sandstone porphyrites and lamprophyres which often follow these lines of disruption, as sills. The porphyrites and lamprophyres have also been injected along the course of the foliated epidiorite dykes, but this is of more frequent occurrence in the case of the Tertiary basalts, which often depart from their course and follow that of an epidiorite dyke for a mile or so, before resuming their original trend.

(*b*) *Area west of Loch Linnhe* (*Sheet 53.*)

Mr. Wilson

In Sheet 53, Mr. Wilson met with granulitic siliceous schists and muscovite-biotite gneiss like those described in last year's report. He followed the main mass of epidiorite in Glen Scaddle across the watershed to the south, where it covers a considerable area, surrounded by its belt of acid gneiss (see former report). He also found to the north of Glen Gour isolated masses of epidiorite with rings of acid gneiss. A new feature in the geology of the region is the occurrence of patches of black and white marble along the margins of some of these intrusive masses.

The region is mountainous and wholly within deer forest, and consequently the population is limited to a few families. The water supply is abundant, particularly that derived from the numerous springs issuing from the epidiorite.

Sections exposed in Ballachulish Railway Cuttings. In order to record the geological structure laid bare in the railway under construction between Ballachullish and Connel Ferry, Mr. Wilson traversed that section of it extending from Loch Creran eastwards to East Laroch. The principal points of interest observable are the evidences of increasing metamorphism exhibited by the slates and phyllites as the granite mass of Ballachullish is approached from the east. The granite itself, which is an unfoliated hornblende-granite, near its junction with the schist, is full of small inclusions of biotite schist and banded hornfels. These inclusions also occur in the Ballachullish granite quarry and add to the expense of its working. The junction of the quartzite and limestone with the Kentallenite mass of Kentallen Bay* is also well exposed in the cuttings. Near the contact, the Kentallenite is fine-grained, the quartzite is hornfelsed and the impure limestone is altered into a calc-silicate hornfels.

LOWER OLD RED SANDSTONE.

Messrs. Peach and Kynaston.

Area north of Loch Melfort. An area of about 10 square miles of the Lorne Volcanic Series was mapped to the north of Loch Melfort by Messrs. Peach and Kynaston, in connection with the completion of the north-eastern portion of Sheet 36.

*For description of the rock see Report for 1896, p. 22, also paper by Messrs. Kynaston and Hill, *Quart. Journ. Geol. Soc.*, vol. lvi., p. 531.

The margin of the volcanic series forms a well marked line of crag, well seen to the north of Loch Melfort, and the contact with the older schists is everywhere of a markedly unconformable type. The old surface upon which these flows were poured out was evidently hilly and uneven, and broken into ridges and hollows. This is proved by the gradual rise of the base line of the volcanic series from near sea-level on the east side of Kilchoan Bay, to a height of over 800 feet in the area about An Coire; while the occasional occurrence of inliers at some height within the volcanic plateau serves to mark the site of some of the more prominent ridges of the older rocks. Similiar evidence is afforded in the promontory of Degnish. Messrs. Peach and Kynaston.

The lavas rest directly upon the older schists without the occurrence of any intervening conglomerate, though frequently a thin bed of breccia may be seen underlying the lowest flow. The upper surface of the flows is often slaggy, and flow-brecciation is common. The dip is seldom more than 15°, though occasionally higher angles have been noted. The general direction of inclination is to the north-west.

On the whole the lava-flows of this area are exceedingly uniform in composition. They may all be assigned to the more basic division of the andesites, while some are closely allied to the olivine basalts. There is a complete absence of acid types of lava. The rocks are dark purple, sometimes greyish in colour, sometimes compact, and occasionally highly vesicular. The compact varieties are usually the fresher and often show a well developed flow-structure.

Some of the lavas are evidently closely allied to basalt. Thus a well marked basaltic flow may be traced for some distance to the north-west of Melfort. It is a hard, almost black rock, fine-grained, and closely resembles basalt. Under the microscope (10356) a specimen, from half a mile north of Melfort House, shows numerous more or less idiomorphic olivines, mostly quite fresh and only occasionally altered into serpentine, in a matrix of small plagioclase laths, augite grains, and magnetite. There are no plagioclase phenocrysts and the rock is evidently closely allied to the olivine basalts, though the ground-mass is rather of the andesitic type. This flow is certainly most remarkably fresh for a Lower Old Red Sandstone lava, and there is no other instance in the Lorne area where rocks have been found containing unaltered olivine, though basic lavas, containing numerous pseudomorphs after olivine, are very common.

Fragmental volcanic rocks have only occasionally been met with in this area. A band of about 20 feet of fine-grained reddish ash, occurs to the north-west and west of Melfort, intercalated with the basic flows. A thinner band of similar material may be seen underlying the andesitic crags in the Pass of Melfort.

Between Degnish and Ardmaddy Bay where the rocks of the volcanic platform mark the steep coast line, a bed of decomposing red agglomerate lies near the base of the series. The dip here is seawards, in consequence of which large masses of the

Messrs. Peach and Kynaston.

piled up lavas, hundreds of yards in extent, have been detached and have slid bodily seawards over the surface of agglomerate, giving rise to very extensive landslips.

Mr. Kynaston.

During the mapping of the volcanic series of south-western Lorne an examination was made by Mr. Kynaston of the basal conglomerates at the north-east end of the Island of Kerrara, and in the area north of Loch Avich.

North-east end of Kerrara. Two small patches of conglomerate, formerly mapped by Mr. R. G. Symes, were examined, one at the promotory of Rudh 'a Bhearnaig, and the other slightly further to the E.S.E. near the old burial ground. The conglomerate rests upon an uneven surface of the black schists and is often seen filling cracks. In both of these patches, boulders of granite are very numerous, and are all of the same general type. Further to the south-west a small patch of conglomerate is seen on the south side of Port 'a Bhearnaig, but the granite boulders are not so common. In the rock of Rudh 'Ardan Duinein, no granite boulders could be seen, but boulders of epidosite are plentiful.

The granite boulders vary from a fine-grained pinkish granite or quartz-diorite to a coarse greyish diorite. The coarser varieties are much decomposed. Under the microscope the rocks are seen to be mainly quartz-biotite-diorites, and some are biotite granites with a considerable development of interstitial micropegmatite (10,291, 10,297, 10,298). One specimen shows lines of crushing in a granophyric rock (10,298).

Boulders of the normal basic types of andesite are everywhere common in the conglomerate, associated with the blocks of hornblende-andesite, and some of porphyrite and quartz-porphyry, resembling the rocks which form the later dykes.

Area north of Loch Avich. To the north-east of Creag Dubh there are some fine crags of conglomerate containing blocks of andesite, quartz, quartzite, schistose grits, black schist, and epidiorite, and an occasional one of felsite. The epidiorite boulders belong to local types and may range up to 5 feet in diameter. All, except those of slaty rocks, are well rounded. To the south-east of this exposure some conglomerate or breccia is seen resting upon the andesite.

At Creag Dubh a boulder of epidiorite, about 7 feet across, was seen in the conglomerate. At the base of the west side of the crags the junction between the conglomerate and the schists is well seen. It rests upon a sloping surface of fine-grained, greenish chloritic quartzose schists, the surface of which has a smooth and polished appearance, and the junction is perfectly sharp.

Messrs. Peach and Kynaston.

Volcanic rocks and associated sediments of Glencoe.—In the early part of June the Glencoe area was visited by Mr. Kynaston, in company with Messrs. B. N. Peach and D. Tait, for the purpose of searching the shaly beds associated with the lava flows, for fossils.

The result of the examination of the sedimentary bands was the discovery by Messrs. Tait and Peach, in certain zones of dark grey and black shale, of plant remains of Lower Old Red Sandstone age. These were identified as belonging to the characteristic Lower Old Red Sandstone genus *Psilophyton*, and this identification was subsequently confirmed by Mr. Kidston. *Pachytheca* was also found. The best specimens were got by Mr. Tait in a thin band of black shale which occurs associated with purplish, reddish, sandy shales, marls, and conglomerate, at the base of the north-east crags of Stob Dearg, west of Kingshouse. These beds rest immediately upon the upturned edges of the quartzite series, and are overlain by the bedded breccias with gritty bands, which underlie the rhyolitic lavas of the Buchaille Etive Mor. Specimens of *Psilophyton* were also found in a bed of black shale on the south-east side of Stob Dearg, and in a bed of dark grey shales and mudstones, underlying the basic andesites on the north side of Glencoe. Messrs. Peach and Kynaston.

The discovery of these fossils at once settles the Lower Old Red Sandstone age of the volcanic series of Glencoe and the Blackmount, with which the fossiliferous beds are associated, and at the same time intimately connects the Glencoe series with that of Lorne.

NEWER INTRUSIVE IGNEOUS ROCKS.

DIORITE AND GRANITE.

Area south of Loch Melfort.—In this tract there are many intrusions of diorite, which vary considerably in size. Their mode of occurrence, and the strong resemblance which the rocks bear to one another, suggests that the different exposures are merely the subsidiary off-shoots and protrusions of a much larger underlying mass. Indeed, the relatively large area of contact alteration seen in the surrounding schists, would seem to give considerable probability to this view. Mr. Kynaston.

The largest of the intrusions occupies the highest portion of the ground, and is a roughly oval-shaped mass, being elongated in an east and west direction. It becomes fine-grained at the margin, and decidedly coarser in the more central parts. The exposures often show a good deal of shattering and weathering, the crags often assuming more or less rounded forms. The majority of the hill features are smooth, rounded, and covered with grass and thin heather, while the highest portions of the ground form peaty flats, with occasionally protruding rocky knobs. The ultimate stage of the weathering is a fine, felspathic, micaceous sand, which covers large portions of the area, and often encloses rounded, boulder-like lumps of partially disintegrated diorite. The contact between the diorite and the altered schist which surrounds it, is sometimes clear and well-defined, but is often, on the other hand, of an exceedingly complex nature; the hornfels being traversed by numerous small veins and strings of the igneous rock, or, frequently, portions of the schist have been broken up and floated off by the intruding magma, which, in this way, has produced at its margin a breccia of hornfels fragments in a fine-grained, dioritic matrix.

ynas- Occasionally the diorite appears to pass into a variety of porphyrite. Under the microscope, however, there is a sharp distinction between the two rocks. Moreover, the behaviour of some of the minerals in the porphyrite is exactly similar to that of the secondary minerals in certain contact altered igneous rocks, such as andesites, and the phenomena suggest that the porphyrite constitutes an earlier, though closely-related. intrusion, which was subsequently succeeded and altered by the more normal type of the diorite. So that we may probably have in these cases compound intrusions, consisting of an earlier, and sometimes more basic, porphyrite,which was followed by diorite. Dyke-like intrusions and irregular masses of a highly felspathic and more acid material are also sometimes associated with the diorite, and may occur along the margin, or in the more central portion of a mass.

The essential minerals of the normal type of diorite are plagioclase, hornblende, and biotite, together with a somewhat varying proportion of interstitial alkali-felspar and quartz. A pale augite and sometimes also prismatic brown hornblende are not uncommon in the more marginal facies. The biotite is of later formation than the plagioclase and is moulded upon it—a feature which is very characteristic of the diorites of the Ben Cruachan and Glen Fyne areas, and also of Kentallenite. These Kilmelfort rocks are quartz-mica-diorites of the tonalite type, and closely resemble some of the dioritic modifications of the Ben Cruachan granite and the quartz-diorites of the Criffel mass, in the Southern Uplands. The slightly more basic marginal facies recalls the fine grained marginal basic modifications of the Cheviot granite.

There is no field evidence in this area that would define within strict limitations the geological age of these diorities, but it can hardly be doubted that they belong to essentially the same period as the later granitic and dioritic masses of other parts of the south western Highlands, such as those of Ben Cruachan, Ben Nevis, and Glen Fyne, and of the Southern Uplands. All the dioritic masses of this area are accompanied by a contact alteration of the surrounding schists of the hornfels type. As one approaches the diorite, the phyllites gradually pass into the condition of a dark micaceous hornfels, and the calcareous schists are altered into calc-silicate hornfels. A banded hornfels may be produced by the interlamination of these two types. The epidiorite sills also show some alteration. The alteration is of the same type as that observed along the marginal area of the Ben Cruachan granite, and described in detail in the Annual Summary for 1898, though apparently in the present area the alteration is not quite so intense.

. *Loch Melfort Area.*—Dykes and sills closely associated with and the larger intrusive masses are of common occurrence in this ion. area, and they are most numerous in the area to the south of Kilmelfort. They vary considerably in size, and consist of different varieties of porphyrites and felsite. In the area occupied

by the andesitic lavas intrusions of porphyrite are not nearly so common, as they are either to the north-east, or to the south. The normal trend of these rocks is in a general N.E. and S.W. direction. In the area occupied by the schists, sills of biotite-porphyrite are of common occurrence, both to the north and south of Loch Melfort. Sills of a more acid type are also frequently met with. They differ from the normal porphyrites in the rarity of ferromagnesian minerals. Some of them might perhaps be termed felsites, but they are usually so highly decomposed that it is often impossible to tell the character of the original rock. Messrs. Peach and Kynaston.

Craignish.—Passing southwards from the granite area into Craignish, the dykes and sills belonging to this series are at first very numerous but gradually decrease in number and size towards the Point of Craignish. The rocks comprise felsites, porphyrites, mica-porphyrites and lamprophyres. They appear between the epidiorite sills and the schists over part of their course, and their trend is therefore in a N.N.E. and S.S.W. direction. Messrs. Peach, Muff and Bailey.

Shuna, Torsay, Luing, and Islets to West.—Dykes and sill-like masses of felsite, porphyrite, and lamprophyre occur in considerable number over most of these islands. On the west shore of Luing, N. of Blackmill Bay, some acid felsitic sills may be seen to traverse mica-porphyrites. They usually follow the direction of the planes of schistosity of the slates, which is nearly N. and S. These dykes and sills increase in number and size from south to north; indeed they seem to form a belt distinct from those of Craignish, and may have emanated from a different source. Messrs. Peach and Bailey.

Scarba and Lunga.—These islands seem to lie within the same belt of intrusion as that of Luing. Dykes of felsite, porphyrite, and lamprophyre are very numerous near the N. end of Lunga, while they decrease in number southwards. Only a few reach the southern shore of Scarba, and still fewer appear on Jura. Their trend is usually directed by the planes of schistosity, but a few follow the course of thrust-planes and cleaved epidiorite dykes. On the extreme west coast of Scarba they form vertical dykes, which may be seen to cut the quartzites in parallel groups with an E. and W. trend. These are undoubtedly of no great breadth, but are interesting as they exhibit fluxion and spheroidal structures along their edges in a marked manner

Crinan District.—In the Crinan area there are only a few dykes of porphyrite and lamprophyre. Their trend is usually N.N.E. and S.S.W., but two were observed to follow lines of crush in a W.N.W. direction.

TERTIARY INTRUSIVE ROCKS.

The whole district is traversed by a series of dykes, consisting for the most part of olivine-basalts, dolerites, andesitic basalts, and a very few of trachyte and felsite. They are very numerous in the ground on both sides of Loch Melfort, where they traverse Messrs. Peach and Kynaston.

Messrs. Peach and Kynaston.

the schists, and the Old Red volcanic and intrusive rocks indifferently. In this region they are for the most part basic, some, however, are andesitic, in which case they are often glassy. They are numerous in Craignish, where a good example of a multiple dyke, made up of no less than ten separate intrusions within the same fissure, was observed by Mr. Muff. They decrease in number in the islands to the west of Luing, and only comparatively few are found in the Crinan area. Their general trend is usually N.W. and S.E., but they are often diverted from their course along lines of fault, and of older igneous intrusions such as the epidiorite dykes on Scarba. They were found by Mr. Kynaston to be very numerous in the ground mapped by him in the Loch Scamadale area in Sheet 45, where dykes of trachyte were also recorded. He also found another mass of agglomerate, about 100 yards wide, further south than any previously observed, which probably represents another Tertiary Volcanic vent along the same line of fissure as that mentioned in last year's Summary. (*Summary of Progress*, 1888, pp. 153-154; 1901, pp. 150-151.)

PLEISTOCENE AND RECENT DEPOSITS.

Glacial.

Messrs. Peach, Kynaston, Crampton, Muff and Bailey.

The whole area mapped in Sheet 36 during last season bears evidence of having been overridden at the period of maximum glaciation by land ice, which moved in a general westward direction.

Small patches of Boulder Clay are found in Craignish and to the north of Loch Melfort and on Luing, but it nowhere covers much of the surface. In Scarba and Lunga the patches of this deposit contain numerous boulders of granite, porphyrite, epidiorite, and schists derived from the interior of the mainland. Boulders of these rocks are likewise scattered over the general surface of all the outlying islands, rocks, and holms.

Only small nests of Boulder Clay, often of a red colour, occur in the Crinan area, many of the included stones being foreign to the district, such as sandstone, porphyrite, and andesite, from which it is clear that the ice which gave rise to the deposit must have traversed an area of Old Red Sandstone rocks. This evidence is in harmony with that obtained in Kintyre, Jura, and Islay.

Traces of moraines were found in the plateaux both to the north and south of Loch Melfort. On the west side of Cruach, Scarba, small moraines cross the hollows emanating from that hill, showing that the island of Scarba must have nursed independent glaciers during the later glaciation. Over the other parts of the district the phenomena are attributable to the earlier and more general glaciation.

Rock Basins.

Mr. Muff.

The four lochans north of Ardfern lie in hollows trending N.N.W., and S.S.E., parallel to the strike of the schists. These hollows are crossed transversely by basalt dykes, which, in nearly

every case, project above the level of the ground, forming a rocky embankment from 2 or 3 feet up to 40 or 50 feet high, across the floor of the valley. In some cases the dykes are covered by vegetation, but in others the bare rock may be traced from side to side. Mr. Muff.

Since three of the above lochans lie between basalt dykes, which run to the north and to the south of them, there can be little doubt that the lochans lie in rock basins.

Raised Beaches.

Traces of the 100 feet beach either in the form of deposits or of a rock notch were met with along the whole sea-board of the area. The largest development of such deposits was found in Craignish, along the Crinan Canal and south of Loch Crinan. In the deposits belonging to this beach and its sub-littoral zone Mr. Muff found shells (*Littorina obtusa*) at a height of 70 feet above datum level and non-littoral shells in the bed of the Barbreck River a little above sea level in the Craignish area.

Newer beaches at a lower level probably representing the 50 feet and 25 feet beaches make considerable patches of arable land in Craignish and Luing and form a fringe along the low lying shores; while on the rocky shores of the mainland, the outer islands, holms, and skerries, the rock notches representing them are conspicuous features. In one of these deposits in Craignish, Mr. Muff found abundant littoral shells, such as *Littorina littorea, L. obtusa, Mya truncata, Mytilus tenuis, M. modiolus, Tellina tenuis*, and a large species of *Balanus*. In the west of Scarba and other quartzite islands storm beaches of well-rounded quartzite blocks, quite bare of vegetation, accompany each raised beach, reminding one of the west coast of Jura.

Alluvium.

The largest area of freshwater alluvium is found on the Barbreck River at the head of Loch Craignish. Smaller patches of alluvium are found at the bottom of most of the valleys throughout the area but these are often hid under a coating of peat. Some of these alluvia represent silted up lochans, many of which occur in the area south of Crinan.

Peat.

South of the Crinan Canal, peat is found chiefly along the bottom of the deep narrow valleys where schists of sedimentary origin crop out at the surface. It, however, sometimes creeps on to the flat topped ridges. It practically covers the flat tableland south of Loch Melfort and spreads out along the boulder clay and raised beaches in Craignish. North of Loch Melfort it is usually found on the flat topped hills. It also occurs in considerable patches on the islands, especially those consisting of quartzite, where it fills every hollow and even creeps down on to the raised beaches and rock notches.

ECONOMICS.

The chief industry connected with the rocks of the region is slate quarrying, which supports a considerable population in Seil, Luing, and Belnahua, as already stated.

Limestone was formerly much quarried and exported from Degnish, Shuna, Luing, Craignish, and the Loch Melfort region, but this has been discontinued.

No very good building stone is found, but the epidiorite sills afford a fairly good material for that purpose, and blocks of considerable size can be obtained, especially where the rock is well foliated. The new hotel at Crinan is built of this material. It is also used as a building stone in Craignish.

Road metal is everywhere plentiful and of excellent quality as the whole country is traversed with dykes of basalt and porphyrite. Quartzite and limestone are also used for this purpose where they are more easily procured than the basalt.

Peat is everywhere obtainable, but owing to the scarcity of labourers and the difficulty experienced in drying the material, it is found cheaper in most places to import coal.

2. CENTRAL AND EASTERN ROSS, WITH PARTS OF INVERNESS-SHIRE AND SUTHERLANDSHIRE.

Mr. W. Gunn, District Geologist.
Mr. C. T. Clough, M.A.
Mr. L. W. Hinxman, B.A.
Dr. C. B. Crampton
Mr. E. H. Cunningham Craig, B.A.
Dr. J. Horne, F.R.S. (Acting.)
} Geologists.

The principal formations met with in this district are Highland Metamorphic Rocks, including various gneisses and schists of igneous origin, Granite, Old Red Sandstone, Glacial Deposits, Peat and Alluvium.

HIGHLAND METAMORPHIC ROCKS.

Mr. Clough and Dr. Crampton

Deanich District.—Most of the rocks consist of siliceous granulitic schists of the Moine series, with mica-schists, including biotite-schist, muscovite-biotite-schist, sometimes with grains of secondary albite, and muscovite-biotite-gneiss. The general strike near Meallan Ban and Beinn a' Chasteil is nearly N. and S., but on passing northward from these hills it changes gradually and becomes N. N. E. or N. E., or even E. and W., as on Dunan Liath. The dip—which may merely represent the inclination of limbs of isoclinal folds—is E., S. E., or S., and the degree, which is rarely more than 20 degrees at the western end of Gleann Beag, becomes much steeper eastward, and near Meall a' Ghrianain, the beds, striking N. and S., are often vertical, or in places dip steeply W.

The widest band, in which there is a large proportion of micaceous beds, is a continuation of that mapped last year across Meall an Torcain (near Aultguish). The breadth shows a general

increase in a northerly direction, from 150 yards on Meall an Torcain to two and a half miles near the head of Gleann Beag. The increase in breadth northwards is accompanied by an increase in coarseness of structure, and by the introduction of thin seams, rich in zoisite and hornblende,* which were not observed on Meall an Torcain. It is hence suggested that the two margins of the band represent one stratigraphical horizon which has been isoclinally folded, and that the wide outcrops northwards, include more horizons than the thin outcrops further south. Mr. Clough and Dr. Crampton.

For some distance E. and S. E., of this broad belt, thin bands of micaceous schist are common. Numerous thin pegmatitic streaks and lenticles, rarely more than a few inches thick, mostly parallel to the foliation and often folded with it, appear in the schists. Even where such streaks occur in adjacent bands of mica-schist they are hardly ever seen in the associated siliceous schists. Besides the folded pegmatites, there are white muscovite-pegmatites sometimes 5 yards broad, which run chiefly along the micaceous schists but frequently act as dykes crossing the bedding in all directions.†

East of the broad micaceous band above referred to, nearly as far as Deanich Lodge, the predominating rock is a blocky siliceous schist, very false-bedded and with the minor laminae often in curves. Still further east, flaggy siliceous schists are met with and occupy most of the long hollow between Deanich and Loch Toll a' Mhuic, and the sides of Gleann Mor. Remains of clastic grains are not uncommon in these flaggy schists, and increase in number in an easterly direction towards Beinn a' Chasteil.

A remarkable siliceous band occupies Beinn a' Chasteil—a hill about two miles south-east of Deanich Lodge, and has been traced for several miles to the north-east. Fully a mile broad, and of uniform lithological character, it is composed of massive beds of a pale pink or white colour, and includes layers in which the original pebbly character is still distinct. Most of the pebbles consist of quartz of a faint amethyst colour, some of felspar, usually ungranulitized, others of a rock resembling jasper, and a few of a composite rock. Lenticular patches, now composed of micaceous schist, and perhaps originally of the nature of "galls," are also common. The summit of Beinn a' Chasteil is in places strewn with small quartz pebbles, some as large as a bean, which have been weathered out of the rock. Near the western margin of the band two thin beds of a silky phyllitic character are seen, and are evidently in a less altered condition than the micaceous schists which occur farther west. Dr. Crampton.

Augen-Gneiss or Foliated Granite.—A little S.E. of Crom Loch, and near Carn nan Aighean, is a granitic rock, representing the western margin of the augen-gneiss described in previous

* Thin seams of a similar character, in one-inch Map 92, have been described by Mr. Gunn and Mr. Teall. Summary of Progress for 1897, p. 41.

†This series of dyke-like pegmatites is a continuation of that described on Creag Rainich in the Summary of Progress for 1902, p. 107.

Dr. Crampton. Summaries. The margin of the main mass is irregular, and outside it there are small portions of similar rock entirely surrounded by schist, but in general the strike of the schists is nearly parallel with the margin of the foliated granite. The schists are somewhat altered for a distance of about half a mile, but, owing to the almost complete absence of argillaceous sediments, the alteration is less evident than in the Kildermorie area.* The granitic rock varies in grain considerably. Some varieties are without any distinct foliation and contain large beautifully zoned felspars and pea-like blebs of bluish quartz; others are well foliated and closely resemble the augen-gneiss of Inchbae. Angular and rounded masses of more basic material, varying in length from an inch to several yards, appear within the augen-gneiss. Close to the margin, however, these basic inclusions do not seem to occur, though lenticles of schist are not infrequent. The basic inclusions vary considerably in composition, some consist chiefly of hornblende while others are less basic and contain blebs of blue quartz like those in the granitic rock. Most of the basic inclusions are unfoliated, but some are crossed by a foliation in the same direction as that in the enclosing acid material.

Mr. Clough and Dr. Crampton In most of the area, thin bands, evidently intrusive and chiefly composed of hornblende-schist, chlorite-schist or biotite-schist, are rather common. Some of these run nearly parallel with the bedding, others behave as steep dykes or sheets making a small angle with the horizon. In many cases the foliation is in the same direction as that in the adjacent schists, in others it crosses the margins; but in certain bands which show their intrusive origin most clearly, it is parallel to the margins, and not in the same direction as that in the adjoining schists. This fact, combined with the poor development of foliation in certain cases, and the occurrence of some sections in which the schists of sedimentary origin are seen to have been folded and subsequently cut by the intrusive rock, renders it probable that some of the bands referred to were not intruded until after the sediments were already in a schistose condition.

Besides those bands of intrusive origin which are generally schistose throughout, there are some which are only foliated in exceptional cases, generally near the margins. These recall the foliated lamprophyres, and some are certainly of later age than the adjacent more foliated intrusions.

Mr. Clough and Dr. Crampton. *Craigs District.*—Siliceous schists of the Moine series form most of the area. No bands with such large pebbles as those on Beinn a' Chasteil have been observed, but some in Garbh Allt about two thirds of a mile W.N.W., of Cnoc an t' Saic, and probably on the strike of those on Beinn a' Chasteil, contain pebbles which in their deformed state are an inch long. The strike is generally E.N.E., or E. and W., and the dip S.S.E., or S., often at 60° or 70°. On the south side of the main mass of siliceous

* See Summary of Progress for 1901, p., 108.

schist there is a band, often more than half a mile broad, which contains a large proportion of muscovite-biotite-schist and also patches of hornfelsed rocks. The schists in the south portion of the band are usually mixed with irregular sheets and bands of granite rock, now generally foliated and in the form of augen-gneiss, which form a fringe round the northern edge of the great mass of augen-gneiss of Abhuinn Shalachie and Carn Salach. The muscovite-biotite-schist is frequently garnetiferous, and closely resembles the broad band already described near Glenbeg and Toll Lochan (Deanich district); containing, like the latter, thin seams rich in zoisite and hornblende. It seems possible, therefore, that the two bands may belong to the same stratigraphical horizon. Mr. Clough and Dr. Crampton.

The hornfelsed rocks, and those granitic rocks which show little or no foliation, are in places crossed by thrust planes and are much altered near them; the hornfelsed rocks being converted into mica schists, and the granitic rocks into augen-gneisses with a fine granulitic matrix. A fuller account of these thrust planes, etc., is given elsewhere.* Mr. Clough.

In this district no basic lumps have been observed within the granitic rock, but there are several bands of later dark basic rock, partly schistose and chloritic, which traverse the foliated granite and the altered sediments associated with it.

Thin bands of hornblende-schist and chlorite-schist, of intrusive origin, are common in the river Carron and Garbh Allt.

Loch Glass District.—The schists in this area belong to the Moine series and are associated with pegmatites and foliated epidiorites and hornblendites. The dip is S.W. or S.S.W. at angles varying from 15° to 60°, and the strike is generally constant. The broad band of muscovite-biotite schist already described on the south-west shore of Loch Morie, extends across Meall Beag to the side of Loch Glass, where it is more than half a mile broad, without any admixture of quartzose schist. On the west side of this band, quartzose schists appear, but the area to the east, as far as Meall an Tuirc, is chiefly occupied by alternations of blocky quartzose schist, rather micaceous flaggy schist and muscovite-biotite-schist. In the rapid alternations east of Meall Mor are a number of white pegmatites like those at Garve, which contain large crystals of muscovite and garnet; in these alternations also appear the foliated epidiorites and hornblendites. They are generally in the form of sills, often contain garnets, and sometimes inclusions of schist. The foliation-planes in certain muscovite-biotite-schists, near the shore opposite Culzie Lodge show elongated rod-like bodies which are perhaps pseudomorphs after andalusite. Dr. Crampton.

Area North-East of Loch Garve and the Blackwater.—A broad well-defined band of coarse muscovite-biotite gneiss crosses the lower end of Loch Garve, and forms the rocky ramparts of Creag Rogaidh. The rock is often intensely crumpled and Mr. Hinxman.

* See Appendix, p. 150.

Ir. Hinxan. overfolded, and in places contains thin bands of very siliceous material. On the south side of the railway the ground east of the Blackwater is entirely occupied by siliceous Moine schists. Garnetiferous amphibolite is associated with these rocks in many short interrupted sills, but it is not so largely developed as on the west side of the Blackwater.

Ir. Hinxan. *Strathconon Forest.*—The ground is chiefly occupied by the two chief members of the Moine series, the Moine siliceous schists and muscovite-biotite gneiss.

The Moine siliceous schists include highly siliceous bands which may be described as granulitic quartzites, but in which a small amount of biotite in minute specks is always present. Signs of considerable movement are frequent in these rocks, and are shown by "rodding"—the drawing out of the mineral particles in one determinate direction,—and the special development of secondary white mica on the foliation planes.

The most interesting feature of the work in this area has been the recognition of two belts or infolds of granulitic acid and hornblendic gneiss, similar in character to granulitic types of Lewisian gneiss found in the north-west Highlands.

The westernmost of these infolds enters the map on either side of the river Orrin, forming an irregular and interrupted belt about three miles in breadth. The gneiss is here associated with the most siliceous type of Moine schist, with which it is so intimately interfolded that it is often difficult to separate the acid portions of the gneiss from the quartz-granulites. The former is, however, more felspathic, and can generally be distinguished from the latter by its banded appearance and mode of weathering.

Rocks of more basic type occur in rapid alternation with the acid gneiss, and include biotite and biotite-hornblende gneisses, and also a rock in which pyroxene and green amphibole are the predominant minerals, with thin parallel folia of quartz and secondary felspar. A lenticular band of ultra-basic rock containing serpentine after olivine, and pale green hornblende injected with serpentine along its numerous fissures, is associated with these Lewisian rocks in the valley of the Orrin. It is for the most part concealed beneath the river alluvium. On the north side of Carn na Creadha there is a small exposure of pyroxene-hornblende rock which is apparently an altered pyroxenite or peridotite.

The second infold crosses the valley of the Orrin between Tighcoirechairbhe and Corriehallie Lodge. It is about three and a half miles in length, a mile in greatest breadth, and lenticular in shape, thinning out rapidly to north and south, where the extremities are concealed beneath peat mosses. At the eastern edge of this inlier the gneiss is almost entirely of the acid variety, but passing inwards it becomes more and more mixed with bands rich in biotite and hornblende, and in the centre of the fold the acid and basic types alternate rapidly with one another.

Bands of black or dark green hornblende rock, some of which reach a breadth of 30 to 40 yards, can also be traced nearly throughout the area from north to south of this second infold. These bands are thoroughly foliated with the gneiss, but it is possible that they may represent basic dykes intruded into the original complex before the present foliation was produced. The Lewisian gneiss is, at one point only, brought into contact with the muscovite-biotite gneiss, by a N.E. and S.W. fault which crosses the river Orrin and has determined its course for 300 yards. Elsewhere, north of the Orrin, the two rocks are always separated by a narrow belt of siliceous Moine schists. In the southern part of this inlier, and also in that to the west, the intervening area of siliceous schist varies greatly in extent, from less than a quarter of a mile to more than a mile and a half. This discrepancy in the relations of the boundaries of the two infolds to those of the members of the Moine series, may be due in part to folding, but it suggests the effect of overlap accompanying an original unconformity between two formations. **Mr. Hinxman.**

Glen Urquhart District. The greater part of the area surveyed is occupied by rocks of the Moine series.

A zone of muscovite-biotite gneiss associated with kyanite gneiss and a much mineralised limestone runs S.E. from the neighbourhood of Loch Gorm. **Mr. Cunningham Craig.**

A large mass of foliated serpentine occurs in the schists, intruded subsequently to their folding but prior to the later shearing movements. There are also some small intrusions of an older granite rock and pegmatite, later in time than the folding, which have been greatly deformed. The granitic rock now appears as a well foliated garnetiferous muscovite gneiss, of very acid composition. The pegmatites are perhaps less sheared than it, but are almost entirely granulitized.

OLD RED SANDSTONE.

Dounich District.—In the outlier of Old Red Conglomerate on Meall a' Ghrianain some of the boulders of augen-gneiss measure about seven yards across. It has now been proved that augen-gneiss occurs *in situ* much nearer this hill, on its east side, than was formerly supposed. Indeed, a small outlier of similar conglomerate, probably originally continuous with that on Meall a' Ghrianain, has been found about a quarter of a mile N.N.W. of the cairn of Carn nan Aighean, where, at its eastern end, it rests on augen-gneiss. **Mr. Clough and Dr. Crampton.**

On the western slopes of Meall a' Ghrianain there are a few small patches of breccia made of siliceous schist, like that on which they rest or abut. Some of these may possibly be crush breccias, but at least two of them seem to represent broken up schist-surfaces of irregular form, and they are probably of Old Red Sandstone age.

Area N.E. of Loch Garve and the Blackwater.—Half way down the steep hillside that rises above the northern slopes of Loch Garve there occur two small isolated patches, separated by a **Mr. Hinxman.**

Mr. Hinxman. stream, of a curious breccia made up of angular fragments of the surrounding muscovite-biotite gneiss. Both the breccia and the underlying gneiss are pierced by an intrusion of mica-trap or lamprophyre, which contains numerous fragments of both rocks, and appears to have altered and hardened the matrix of the breccia. If this breccia form part of a local basal breccia of Old Red Sandstone age, it is difficult to account for its position, except on the hypothesis that the breccia was laid down on an extremely uneven surface, and that it has been preserved in this locality in consequence of the induration induced by the igneous intrusion.

Mr. Cunningham Craig. *Glen Urquhart District.*—A considerable thickness of Old Red Sandstone overlies the Moine gneisses. The pebbles in the conglomerate beds are almost entirely of local origin.

Dr. Horne. *District of Dores, Loch Ness.*—On the east side of Loch Ness, a small area of Old Red Sandstone was mapped, extending from the shore of that loch east to Loch Duntelchaig. An interesting feature is the development of the basal conglomerate on the moor west of Duntelchaig, and on the prominent ridges of Creag Bhreac, and Creag Bad an Eich near Achnabat. At certain localities the bedding is not apparent, but on Creag Bhreac it can be made out by means of thin sandy intercalations and by the parallel arrangement of the pebbles. The mass there dips to the north-west at an angle of about 10°. On that crag and on the moor to the north-east the conglomerate is traversed by small faults, running in a north-west direction, which have fractured and crushed the pebbles. The latter consist mainly of quartz-schist, flaggy granulitic gneiss, mica-schist, pegmatite, granite, porphyrite, and quartz-porphyry. Indeed, the striking characteristic of the mass is the abundance of pebbles of quartz-porphyry and porphyrite, closely resembling some of the apophyses of the newer granite.

The conglomerates pass upwards into red grits with scattered pebbles and sandstones, exposed on the north-west side of Loch nan Eun Rudha and south-westwards to the farm house of Drummond. A thin representative of the well-known fish-band, consisting of shale with small limestone nodules, has been detected at one locality, viz., on the north west shore of Loch Nan Eun Rudha, where it is apparently intercalated in the grits and sandstones. Next in order come reddish hard grey sandstones, often falsebedded, visible in the Dores Wood, where they dip to the north west at angles from 15° to 35°. In the lower part of the Drummond Burn (Allt da Linne) they are associated with calcareous flagstones and shales.

PLEISTOCENE AND RECENT DEPOSITS.

Glacial.

Mr. Clough and Dr. Crampton. *Deanich District.*—Though there are a few boulders of augen-gneiss on the west side of Meall a' Ghrianain, no boulders either of this rock or of the pebbly grit bands, a little west of it, have been observed in the drift on the west side of Beinn a' Chasteil,

nor do any pieces of augen-gneiss seem to have been carried west of the margin of this rock near Crom Loch and Carn nan Aighean. Here then the ice-movement seems to have been towards the east. Mr. Clough and Dr. Crampton.

The striæ in Gleann Beag run nearly east almost in the direction of the glen. But on the higher ground north of the glen the striæ are N. or N.N.E.

Morainic drift fills all the principal hollows, and is also found on some of the high plateaux between the glens. Groups of moraines of large size occur in the low ground north of Loch Toll a' Mhuic.

A great part of the high plateaux is covered by a wide spread smooth-surfaced deposit which is evidently in the main of local origin, and which often gives good evidence of the rock *in situ* beneath it. It is of considerable thickness on some slopes, and is difficult to separate from drift of undoubted glacial origin. In many places it is now arranged in a series of small terraces, caused by small slips, or soil cap motion, since it was first formed.

Peat covers most of the low ground formed by the augen-gneiss and large portions of the high plateaux formed by the schists. It often contains stools of Scotch fir (*Pinus sylvestris*) in great abundance, and in some cases at heights of 2,000 feet.

Craigs District.—No boulders of augen-gneiss have been noticed on the low hill slopes on the south side of the river Carron, but they are common in the bed of the river; many having evidently been carried down in recent times by burns running northward from the gneiss. The ice carry was generally E. or E.N.E., as indicated by the striæ both on Cnoc an t' Saicd and the northern slope of Carn Salach and other places. Dr. Crampton

Loch Glass Area.—The morainic drift near the road at the south end of Loch Morie contains lenticles of contorted yellow ferruginous sand. A small patch of morainic drift along the N.E. shore of Loch Glass, near the foot of the loch, contains a number of boulders of augen-gneiss. Nearly a mile above the foot, and a few hundred yards from the edge of that loch, a small boulder of conglomerate belonging to the Old Red Sandstone formation was noticed on the surface. This boulder is fully a mile from Meall an Tuirc—the nearest point at which such conglomerate is at present known to occur *in situ*—and should it have come from there, it must have been carried in a direction exactly opposite to that of the main ice-flow in this area. It may, however, have come from some exposure not yet surveyed to the west of Loch Glass.

Meall na Speireig Area.—Except on Meall na Speireig, the solid rocks are almost entirely hidden under drift, and splendid sections of drift occur in the banks of Allt nan Caorach. It is of a pale yellow or red colour, and full of rounded boulders of schist, pegmatite, augen-gneiss and a basic igneous rock not known in the district. Stratified lenticles of yellow sand are in places involved in the drift. Terraces, at heights of about 3[redacted]

Dr. Crampton 50 and 70 feet above the present bed of the river, and corresponding to terraces previously mapped by the late Hugh Miller,* occur near the junction of the Allt nan Caorach and the burn which flows N.E. from near Cnoc nan Each.

Peat covers the whole area except a few patches on Meall na Speireig and a thin strip along Allt nan Caorach. In one small burn it is at least 8 feet thick, and contains three super-imposed layers of Scotch fir (*Pinus sylvestris*) stumps apparently in position of growth.

Mr. Hinxman *Strathconon Forest.*—A fine series of moraines sweeps up the valley of the Rogie Burn to the summit level of the Dingwall and Skye Railway at the Eagle Arch. Carried boulders of the Inchbae augen-gneiss are plentiful along the valley, and the trend of the moraines and direction of striæ indicate an ice movement between E. and E. by S.

At the bottom of the valley and near Loch Garve the moraines are composed of gravelly material, and seem to merge into the high lake terrace which is well marked on the north side of the loch as far as the farm of Rogie.

The upper part of the Orrin valley displays a succession of parallel, terraced, lateral moraines which can be traced along the south side of the glen up to a height of 2,000 feet, or more than 1,000 feet above the level of the river.

Dr. Horne. *Dores District. Loch Ness.*—Numerous striæ were observed on the dip slope of conglomerate on Creag Bhreac and northeastwards along the moor to Loch Ashie where the trend varies from N.E. to E.N.E. and E. 13° N. Indeed the evidence confirms the conclusion which has long been formed that the trend of the ice as it issued from the Great Glen veered from N.E. to E.N.E.

Excellent sections of boulder clay are visible in the Drummond Burn and in some of the streams draining Dores Wood. Moraines, in the form of conical mounds and long sub-parallel ridges strewn with boulders, are to be met with on the moor between Loch Duntelchaig and the south end of Loch Ashie. Very large boulders of Old Red Conglomerate with the characteristic pebbles of quartz-porphyry and porphyrite, derived from the prominent crags at the south-west end of Loch Duntelchaig, are thickly strewn over the ground to the north-east.

On the slope between Loch Ashie and Loch Ness there is a series of parallel strips of peat and alluvium, ranging from a quarter to one mile in length and from 25 to 100 yards in breadth, which run along the strike of the sandstones, that is north-east and south-west. On their north-west side there is an escarpment of sandstone, and towards the south-east there is a dip slope of sandstone partly covered with drift. It is probable that these strike hollows may have been

* Mr. Hugh Miller noticed that the terraces were in part bounded by a lower morainic area, which he supposed to have been occupied by ice at the time of their formation.

deepened by ice action, for at certain localities striæ are found on the dip slopes pointing in a north-easterly direction. Dr. Horne.

On the shores of Loch Ness near Dores there are traces of the 50-feet and 100-feet sea beaches.

PHYSICAL AND ECONOMIC FEATURES.

The Deanich District is entirely in deer forest, and has few inhabitants. It contains a large extent of high ground in the form of broad plateaux, separated by deep glens and indented by rocky corries. The elevation of the plateaux gradually increases in a westerly direction, and near Meallan Ban, and the head of Glenbeg and Coire Mor there is a considerable extent of ground more than 2,500 feet high. The Craigs area consists almost entirely of heathery and peat-covered grouse moor and sheep ground, of moderate elevation; the highest point, on Carn Salach, being only 2,118 feet. A scanty crofting population lives near the Carron, and cultivates the alluvial flats of that river. The water for domestic use is usually procured from the small streams which flow into the river. Mr. Clough and Dr. Crampton.

Strathconon Forest.—This is a wild mountainous region with summits rising to upwards of 3,000 feet, and deep glens and corries that carry snow far into the summer. It is entirely given up to grouse and deer, and contains no signs of human occupation save a few solitary keepers' houses, each with its tiny patch of cultivation on the river haugh. The lower portions of the hill sides are ice-worn, bare and rocky, but on the flatter summits and upper slopes there is often a fairly thick covering of drift, as well as wide peat mosses of considerable depth. Mr. Hinxman.

The alluvial flats along the upper course of the Orrin are grassy or peat covered. To these peaty flats the deer resort in the spring to crop the young shoots of the cotton grass (*Eriophorum*), on which deer and sheep are said to thrive after the winter better than on any other natural food.

District of Dores, Loch Ness.—In the lower raised beach west of Dores Church there is a deposit of fine clay which is now used in the local pottery works. Dr. Horne.

3.—East Highland District.

Dr. J. Horne, District Geologist (Acting).

Mr. G. Barrow
Mr. L. W. Hinxman, B.A.
Mr. J. S. Grant Wilson
Mr. Kynaston, B.A.
Mr. E. H. Cunningham Craig, B.A.
} Geologists.

HIGHLAND METAMORPHIC ROCKS.

Gaick Forest.—In the tract mapped by Mr. Barrow which lay to the south of Gaick Lodge, the parallel banded Moine gneisses are typically developed. The colour banding of the gneiss has a persistent dip to the north at angles varying from 5° to 20°. Mr. Barrow.

Mr. Barrow. in an opposite direction to that observed in the Garry area. in the latter district, all but the more massive and less band varieties contain much microcline, showing the typical cr hatching, and this mineral is specially abundant in the ty rich in brown mica, which must have been originally of a mc shaly nature. There is here one small band, usually containi epidote or some other lime-silicate, and generally small garne also noted in the Garry area, which, from its frequent repe tion by folding, suggests that the series is of no great thickne

Numerous veins of granite and pegmatite traverse t gneisses of this region. From the evidence in the area examin by Mr. Barrow, he infers that they belong to three grou derived probably from different magmas; each group havi apparently a different trend.

The first type, the product of the biotite-granite magma, unfoliated and is represented by a few thin veins in the easte part of the ground, where they are undoubtedly cut by t pegmatites of the second series. The latter belong to the bioti muscovite magma and are represented in the middle portion the Gaick Burn by a number of veins of associated granite a pegmatite, often of considerable thickness and occurring in grou which trend in a S.S.E. direction. These veins decrease number and size to the south, east, and west of the Gaick Bu The occurrence of pegmatite, either in the middle, on one side, on both margins of a vein is interesting, as it suggests that t material has not been forced out as so constantly happens other areas. This feature may be due to two causes. First, t highly crystalline condition of the Moine gneisses suggests th the temperature may have been so high that rapid consolidati could not take place. Indeed the final cooling may have p ceeded so slowly that segregation was possible *in situ*. Secor the unbroken condition of the colour bands of the gneis suggests that the latter entirely escaped the crushing action often met with in the more southerly areas. Hence the gran material may have escaped the dynamic action in this area, the forces may have ceased before the consolidation began.

The third series consists entirely of muscovite-pegmatite vei which trend in an east and west direction, and steadily incre in number and size to the west. They are the typical unfoliat pegmatites derived from the muscovite-biotite-gneiss magn described in a communication to the Geological Society of Lond in 1893 by Mr. Barrow.* These intrusions are cut by a ser of faults which do not affect the far more recent granite mass

The rocks belonging to the newer granite consist of dykes a sills of acid, intermediate and basic material; but by far t most important constituents of this group, in the Gaick ar are the sills or horizontal sheets of quartz-porphyry. Th sheets, which vary in thickness from 20 to 50 feet in the a surveyed by Mr. Barrow, are rather pale in colour and very ac with crystals of quartz. Their edges are fine-grained, and th

* *Quart. Journ. Geol. Soc.*, vol. xlix. p. 330.

mode of occurrence suggests an approximation to the nearly horizontal sheets of quartz-porphyry of Tertiary age in Eigg. In other words, in place of showing deep-seated phenomena like the granite veins they suggest an approximation to the volcanic conditions seen in the lower shales of that island. Mr. Barrow

The lamprophyres also, have in places a sill-like mode of occurrence and often present a point of special interest. It is clear that over a very large area the newer granite intrusions were contemporaneous with an epoch of considerable faulting, and these faults in this district often bend over and become minute thrusts inclined at a low angle. The lamprophyre sills sometimes occur along these planes, in which case they present on their margins either a sheared aspect or a preconsolidation foliation. This fact is of importance, because the lamprophyre intrusions are so clearly later than the crystallisation of the Moine-gneisses that their foliation can not in any way be connected with the movements concerned with the production of these gneisses. The two are clearly separated by an interval of great faulting.

In the tract mapped by Mr. Kynaston which lay to the west and south-west of Gaick Lodge, the schists of Moine type consist mostly of banded quartzo-micaceous granulitic rocks, fine to medium-grained, and frequently flaggy and with bands rich in biotite. Some parts are more massive and quartzose, while others again are highly felspathic. The dip of the limbs of the folds is seldom higher than about 15°, and frequently these are seen to be lying almost flat, as, for instance, in many of the crag sections. The sharp isoclinal type of folding may sometimes be observed to the west of Loch an t' Seilich. Folded and puckered quartz veins are also fairly common in some places, and appear to be older than the period of the folding of the area. A mottled band, a few inches thick, showing small patches of ferromagnesian minerals and some epidote, was traced for some distance on the west side of Loch an t' Seilich and on the west side of Bogha-Cloiche. Mr. Kynaston.

The greater portion of the area surveyed is seen to be traversed by numerous veins of pegmatite and fine-grained granite. The pegmatites usually consist of a coarse aggregate of pink felspar, quartz and muscovite. Biotite-pegmatites, without any muscovite, are also occasionally met with, and sometimes in the smaller veins there is an entire absence of mica. The coarse muscovite-pegmatites always constitute the larger veins and sometimes attain a breadth of 7 or 8 feet. They traverse the schists in almost any direction, and frequently lie parallel to the banding.

Small veins of granite are also exceedingly common, especially to the west of Gaick Lodge, and gradually become fewer in number further to the south. They consist of fine to medium-grained pinkish or greyish biotite-granite. The proportion of biotite varies considerably, and there is sometimes also a little white mica present, and occasionally the veins are rather of the aplite type. They vary in size from a few inches up to 5 or 6

Mr. Kynaston.

feet in breadth. They are closely associated with the pegmatites, the granitic material being sometimes interbanded with pegmatite, or the granite vein may show a central portion of pegmatite, or again pegmatite may occur along the margin of granite. The pegmatites also occasionally cut the granite veins.

Sills of quartz-porphyry are very numerous to the west and north-west of Gaick Lodge. They appear in most cases to lie almost horizontally and may attain a thickness of 40 or 50 feet. They become compact at the margin, where they also often show a platy structure due to flow. They belong to the Glen Tromie type of quartz-porphyry, and show phenocrysts of idiomorphic quartz, felspar, and frequently biotite, in a pale pinkish felsitic or microcrystalline matrix. The proportion of phenocrysts to groundmass varies considerably.

Besides these sills of typical quartz-porphyry, there are also some red felsites, which behave rather as dykes, and these are seen sometimes to cut the quartz-porphyry sills. They usually show no conspicuous phenocrysts to the naked eye, though sometimes, as in the rock of Creag Dearg, 1½ miles South West of Gaick Lodge, small felspars and quartz grains may be recognised. A well-marked flow structure may often be observed along the margins of these intrusions, occasionally accompanied by parallel bands of small spherulites.

Intrusions of lamprophyre are fairly common, though, perhaps, somewhat local. They are mostly fine or medium-grained dark greyish and greenish hornblende-lamprophyres, though considerable variations occur. Some of the coarser types appear on the east side of Sgur Dearg, west of Gaick Lodge, and in the south-west part of the area, especially on the west side of Loch an Duin. The lamprophyres usually behave as sills, though sometimes as dykes. Sometimes hornblende is the predominating ferromagnesian mineral, and sometimes biotite, the more felspathic types usually being richer in biotite.

One of the sills apparently belonging to this group, about 10 feet in thickness and occurring about one mile west of Bogha-Cloiche, west of Gaick Lodge, is cut by several small pegmatites and by a coarse muscovite-pegmatite, of about 3 feet in width. In one place the lower portion of the sill passes into a fine-grained biotite-granite. The upper and central portions are decidedly more basic and consist of biotite and prisms of green amphibole in a felspathic matrix, which shows under the microscope a large proportion of microcline. The structure recalls that of some of the syenitic lamprophyres associated with the newer granites of Argyllshire. If this rock is of newer granite age, the pegmatites which clearly cut the sill cannot belong to an older period.

Mr. Cunningham Craig.

In the eastern part of the Forest of Gaick Mr. Cunningham Craig obtained evidence which enabled him to subdivide the Moine gneisses into certain lithological zones.

To the east of Loch an t' Seilich and Gaick Lodge there is a line of cliffs and steep crags, affording a continuous section about two miles in length and from 750 to 1,300 feet in height; the

lower part being often masked by screes. The section runs approximately north and south at a slight angle to the strike of the beds and the folding, and it is thus possible to trace out each bed or fold along the cliff faces, and to measure approximately the throw of faults which cut the line of section. Mr. Cunningham Craig.

The folding is flat and perfectly isoclinal, with the overfolds towards the west and north-west as a general rule, so that it is only when the crest or trough of a fold is approached that the folding can be recognised, but there is very little repetition of the beds on a small scale, such as is common when the flexuring is shallow. The folds are large and deep though lying almost horizontally, and there is no superposition of one fold in a bed directly above another fold in the same bed. Hence it follows that in ascending the section, different zones are exposed in sequence, while here and there one of the great folds repeats a portion of the series.

Four zones can be distinctly made out and recognised by their lithological characters in this section; but whether in ascending or descending order, remains to be proved:—

(1) Thick bedded quartz-biotite-gneisses, containing little felspar, and with a very homogeneous, granular, and very slightly foliated appearance on cross fracture. Muscovite is either entirely absent, or present only in very small quantity. This is apparently one of the thickest of the zones, but only a small part of it is seen at Gaick. The rocks of this zone make the best building stone, and generally form bold crags, broken by joints into large square-edged slabs and blocks.

(2) Very thin-bedded, rusty-weathering felspathic schist or gneiss, containing much felspar, and weathering consequently into round-edged and crumbling flakes or slabs. The biotite is not abundant, and is chiefly concentrated along the surfaces of the beds, rather than distributed throughout the bed, forming there a glistening felt, usually accompanied by a proportion of muscovite.

About the junction of zones (2) and (3) a very characteristic mottled band occurs. It is usually 3 or 4 inches thick, and consists of a granular aggregate of quartz and felspar with little mica, containing darker spots or interrupted folia, elongated parallel to the bedding. The latter, when crushed and examined under the microscope, are seen to consist chiefly of epidote and hornblende, with some garnet and zoisite (?). There may be more than one band of this nature at this horizon, but one band at least has been recognised in many localities, in spite of its thinness.

(3) This zone resembles zone (1) in composition, but is not so thickly bedded. It consists of flaggy, quartz-felspar-biotite-gneisses. On a cross fracture the rocks of this zone present a granular arrangement of the constituents, while on bedding planes a felt of both black and white mica is common. There is rather more biotite disseminated through the beds than in zone (1). Under weathering processes the rock breaks up along joints into large rectangular or triangular slabs.

(4) This zone, which is more largely developed than either of the two preceding sub-divisions in the Gaick ground, consists of fine-banded and thin-bedded felspathic gneisses, containing less biotite and more muscovite than the preceding zones. On a cross fracture a finely granular aggregate of quartz and felspar with some mica, not well orientated, is observed, the appearance being almost granitic in character. Felspar is very abundant, and frequently gives a pink colour to the cross fracture, but the soft, rounded, and rusty weathering of zone (2) is never seen; the rock breaks up into sharp angular fragments, which retain their angularity even when reduced to fine rubble. Felts of mica upon the bedding planes are not common.

Mr. Cunningham Craig.

The four zones described above have been identified and recognised from the Eidart in the east to the Truim in the west, and from Glen Tromie in the north to the neighbourhood of Dalnaspidal in the south. Only in very good sections, however, can they be mapped out with any degree of accuracy. Several other types of rock have been observed in neighbouring areas, but their relations to the above zones have not been established.

The thickness of the gneisses exhibited in the Gaick section alone, after making due allowance for repetition by folding, is not less than 200 and not more than 400 feet.

The ground surveyed in Glen Tromie and the Forest of Gaick is remarkable for the number and variety of the igneous intrusions belonging to the newer granite and diorite. These may be divided roughly into plutonic rocks and dyke rocks, but the distinction is an arbitrary one, as not only every type from a coarsely crystalline pegmatite to a fine spherulitic felstone may be seen among the acid rocks, and an actual passage from a granite to a quartz-porphyry has been observed in more than one locality. Among the rocks of intermediate composition, also, the type varies from fine diorite to the most compact lamprophyre.

The acid intrusions of plutonic type are never of great size; they are the continuation of the veins of granite and pegmatite of Glen Feshie (*Summary of Progress* 1901, pp. 165–166), and as a general rule, increase in number and coarseness of grain when traced towards the Cairngorm and Meall Tionnail granite masses. In the Gaick area the veins consist of granite, aplite, and pegmatite, the two former being usually fine in grain. The pegmatites very frequently occur as coarse, central or marginal zones in the veins of aplite and granite, but occasionally thick masses of pegmatite occur without any accompanying granite. In composition the pegmatites vary from a rock fairly rich in biotite to very acid muscovite-pegmatites without biotite. When the pegmatite occurs as a central zone of a granite vein it is usually much more acid than the finer-grained igneous rock, while miarolitic patches have occasionally been seen. All these phenomena are characteristic of newer granite pegmatites.

The distribution of the pegmatites presents some points of interest. Passing westward and north-westward from Gaick and Glen Tromie the biotite-pegmatites and those with accessory muscovite die out, while the coarse muscovite-pegmatites mentioned in the *Summary of Progress* for 1901 (pp. 166–167) increase greatly in number and size in the northern part of Glen Truim and towards the north-west of Dalwhinnie, where their source may be looked for. One statement in last year's report must be corrected, now that these pegmatites have been examined in greater detail; they appear to be intrusions rather than of segregative origin, although the coarseness of grain is probably not due to a very high temperature, and their introduction is of later date than the regional metamorphism of the country.

In the Gaick area it is noticeable that the pegmatites are more frequent in the lower ground, and decrease perceptibly in number as the hills are ascended. But along certain lines or belts of country there is a marked increase in the number and size of the pegmatites and associated granites. The most notable of these can be traced from a point three-quarters of a mile north-east of Gaick Lodge S.S.E. for a distance of two and a half miles to the Amhainn Gharb Ghaig. At intervals along this line the granite and pegmatite veins become very numerous and large, forming a plexus in which more igneous than sedimentary material is seen. An excellent example of this feature occurs immediately north of the Amhuinn Gharbh Ghaig, about two miles south-east of Gaick Lodge. Mr. Cunningham Craig.

Another increase in the number and size of veins is observed about the lower part of Allt Bhran, in the gorge cut by that stream and for some distance round about it. In this case the belt of country characterised by these intrusions extends in a north-easterly direction, and on Meall an Dubh Catha one mile and a half to the north-east a great development of biotite and biotite-muscovite pegmatites of newer granite type is seen. In this locality the pegmatites may be seen cutting through the quartz veins in the schist, showing that the introduction of the igneous rock took place at a period subsequent to the regional metamorphism. From this locality the pegmatite and granite veins increase in size and number towards the mass of the Cairngorm granite.

The quartz-porphyries are chiefly confined to the higher ground in the Gaick Forest, but in the northern part of the area they descend to the lower ground. They occur as flat-lying sills and attain a thickness of over 100 feet in some places. They are the normal fine-grained porphyries of the newer granite, consisting of idiomorphic phenocrysts of quartz, felspar, and biotite in a microcrystalline or cryptocrystalline base, which sometimes exhibits a beautiful flow structure at the margins.

There are several varieties of dyke rocks of intermediate composition in the area; they are mostly fine in grain, but often have well developed phenocrysts, sometimes of hornblende, sometimes of biotite. Specimens of these rocks have been sent to Dr. Flett for microscopic examination. A fine brick-red felstone, occasionally spherulitic, has also been observed, but is not common.

With regard to the mutual relations of these intrusions some very interesting evidence has been obtained. The quartz porphyries, with some notable exceptions, appear to cut the granites and pegmatites. In the lower part of Allt Bhran and again in the lower part of Allt na Fearna, intrusions of medium-grained biotite granite with pegmatites and aplites have been mapped, and can there be seen passing gradually into the typical quartz-porphyry. In the former case the granite is exposed in the stream section at the bottom of a deep gorge; numerous irregular masses of granite are seen, but none of them reaches high in the section. It appears that merely the top of an under-

Mr. Cunningham Craig.

lying floor of granite is touched in this locality, while the higher ground on either side is characterised by the presence of intrusions of quartz-porphyry. In Allt na Fearna the section is somewhat the same, but not so well exposed. Aplite veins are seen cutting both the granite and quartz-porphyry and the surrounding schist. The exposure of this granite in the low ground is very significant, occurring as it does at a distance of six or seven miles from the main mass of the Cairngorm granite.

The rocks of the lamprophyre group cut the granites, pegmatites and quartz-porphyries almost invariably; in Coire Bhran, however, a lamprophyre is cut by one of the quartz-porphyry sills.

The granites and aplites are occasionally seen to be intruded into the quartz-reefs occupying lines of fault.

The fine brick-red felstones cut alike granites, pegmatites, quartz-porphyries and lamprophyres. North-east of Gaick Lodge a striking case of this may be seen, where one of the north-east and south-west faults cuts off pegmatite veins and sills of quartz porphyry and lamprophyre, while a dyke of the red felstone has been injected subsequently into the line of fault and occupies it for upwards of half a mile.

From the above evidence it will be seen that the intrusion of igneous material was continued for a considerable time, and that though all the igneous rocks have probably been derived from the same magma, local differences in the rate of differentiation may have caused irregularities in the mutual relations of different groups.

Mr. Hinxman

The small area surveyed by Mr. Hinxman, west of Newtonmore, in Sheet 64, is chiefly occupied by the siliceous granulites and coarse flaky muscovite-biotite-gneiss of the Moine series. The relations of these two rock-zones exhibit the usual complex interfolding of the Central Highlands. On the south side of the Spey the general trend of the axes of folding is to the north or north-east, and the dip of the isoclinal folds is to the west and north-west To the north of Glen Banchor there is more variation in the dip, the rocks being thrown into a series of compound synclinal and anticlinal folds.

There seems little doubt that the origin of the granite and pegmatite veins with which the schists of this region are so abundantly permeated, has been found in an intrusion of acid igneous rock which extends from Glen Truim in a north-east direction across the Spey at Cluny Castle to Glen Banchor. Only the eastern margin of this mass has at present been mapped, and it is probable that it has a considerable extension to the west in the direction of Loch Laggan.

The pegmatite veins show an increasing development in the area west of Newtonmore between Glen Truim and the southern slopes of the Monadhliath. They take the form of thin sills or veins of white pegmatite or granite; those showing pegmatitic structures being the most abundant. They are coarsely crystalline to the margin, with no sign of chilled edges.

At the western end of Creag Dubh, above the Laggan Road, these veins increase in frequency, gradually anastomose, and

finally pass, along a line drawn S.S.W. from Lochan a' Chulaibh to Cluny Castle into the solid mass of white granite and pegmatite referred to above. There is no sharp line of demarcation between the two varieties of rock in this mass, the pegmatitic portions merging into the finer-grained granite. Plumose white mica is a characteristic feature of the pegmatite, and while the fine-grained granite contains a considerable amount of biotite, the predominant mica in both varieties is always muscovite. Mr. Hinxman

Nowhere does this granite show any signs of foliation, but, in common with the veins outside the mass, it contains included fragments, as distinct from isolated portions of the surrounding foliated rocks.

On Binnein Mhor, two miles north of Cluny Castle, the granite is distinctly cut by dykes of red felsite or microgranite, and also by a dyke of coarse quartz-porphyry of the Glen Tromie type. The pegmatite veins external to the mass are also cut by the later lamprophyre dykes.

The field evidence, so far obtained, points therefore to the conclusion that this intrusion is later in origin than the last movements which affected the Moine schists, but earlier than the representatives of what are regarded as some of the latest phases of the newer granite.

With a view to settling the important question of the period of intrusion of these muscovite-biotite-granites and pegmatites, and their relations to the newer or Cairngorm granite, a series of specimens from the Glen Truim and Laggan areas were submitted to Dr. Flett for examination under the microscope.

The general results of his investigations corroborate the field evidence, and are briefly as follows:—

The felspars include plagioclase, orthoclase and microcline, the alkali felspars being most abundant in the more acid pegmatitic portions of the mass. Vermicular micro-pegmatite is sometimes present, and a slight degree of granulitisation, almost entirely confined to the quartz, has been detected in some of the sections. The granitic rocks, though more acid in character than the general type of the Cairngorm granite, are considered by Dr. Flett as probably belonging to the newer granites of the Highlands; while in their mineralogical composition they can be closely paralleled among the granites of the Southern Uplands.

From the Gaick Forest Mr. Barrow continued the re-examination of the ground south to Blair Atholl in Sheet 55. The limit of the granite veins, belonging to the second group in Mr. Barrow's classification (see page 94), was traced, and is now engraved on that map. Mr. Barrow.

Intrusions of newer granite age abound in this southern area, none of which are traversed by the granite veins; but in stream sections the latter are often seen to be cut by the basic members of the newer series. That these veins do not belong to the newer granite is shown by the fact that they die away before reaching the newer granite-complex stretching from Glen Tilt to Glen Feshie.

Some interesting occurrences of biotite-granite have been met with near Blair Castle. They show protoclastic foliation, and thus serve to link the unfoliated biotite-granite veins alre[redacted]

Mr. Barrow. referred to, and the Ben Vuroch augen-gniess, with its cataclastic structures due to post-consolidation crushing.

Parts of the Tilt Valley and some portions of the Falar area were also re-examined by Mr. Barrow. The point to which attention was principally directed was the original thinning away to the south-east of the colour-banded rocks which have crystallised as Moine gneisses, which pass through a phase of finer sedimentary material, but always retaining their parallel banding. The Little Limestone always occurs on one margin of these rocks, and its occurrence has been noted and traced in the Tilt Valley and in Glen Banvie. On the other side of the parallel banded rocks is the quartzite, from which it may be inferred that the Moine gneisses lie between these these two rocks, viz., the quartzite and the Little Limestone. As the quartzite often passes insensibly into the colour banded series it is equally clear that there can be no erosion-plane on the margin here.

Mr. Cunningham Craig. The revision of the area between Pitlochry and Blair Atholl, in Sheet 55, was completed by Mr. Cunningham Craig, which resulted in bringing to light additional evidence relating to the great intrusion of epidiorite and hornblende-schist of Beinn Vrackie. The intrusion appears to be a large laccolite, and the regularity with which it conforms to the bedding of the surrounding schists is admirably shown by the thin brown limestone at the top of the Beinn Lawers Schist, occurring almost always within a few feet of the lower surface of the igneous rock.

The upper surface of the laccolite is seldom so well exposed as the lower, and over a large part of the area only the lower surface is seen, where it is continually repeated by folding. The junction of the upper surface with the Black Schist is well exposed, however, in several localities. Induration and hornfelsing of the contiguous rock is observed both along the upper and lower margins.

Mr. Wilson. During the spring, Mr. Wilson completed the revision of the area in Strath Tummel and Strath Tay in connection with the publication of Sheet 55. The boundary line between the quartzite and black schist in Strath Tummel was mapped, and additional evidence was obtained regarding the unconformable relation of the quartzite to the adjacent schists.

On the north side of Loch Tummel, Mr. Wilson found a good exposure of Boulder Bed, identical in matrix and included blocks with that so largely developed in the Schichallion complex. As the Strath Tummel bed lies on the east side of the Loch Tay fault, its occurrence there tends to confirm the conclusion that the Schichallion limestone and black schist are the same as those at Blair Atholl.

PLEISTOCENE.

Glacial Phenomena.

Mr. Barrow. The area surveyed and re-examined by Mr. Barrow includes the whole belt in Perthshire and Inverness-shire, where the great western ice sheet and the local sheet of the east Central Highlands coalesced. It is clear that the western ice accumulated

more rapidly than that of local origin, and dammed back the the latter, thereby arresting all movement along a certain zone. Within this zone no glacial erosion took place; and hence the Moine-gneisses are now so soft and decomposed that they can be dug readily with the hammer. The limit of advance of the western ice sheet appears to be about 2,900 feet; it may have been thicker than this, but it was unable to force back the local ice at all higher elevations. This point is of importance, because the Ben-y-Ghloe mountains rise to a height of over 3,000 feet and hence may have acted as a pivot to the ice movements. The outer limit of the belt of uneroded ground clings always to the south-west edge of these mountains. As soon as this barrier is passed, the trend of the western sheet becomes more and more easterly, till, as explained on various former occasions, it turns due east, then north-east, and finally, on the Stonehaven coast, almost due north, as noted by Jamieson many years ago.* Mr. Barrow

In that part of the Gaick Forest examined by Mr. Cunningham Craig, which consists for the most part of a broad plateau rising nearly to 3,000 feet, and cut by deep and narrow valleys, he found that the later glaciation can be readily traced by its lateral and terminal moraines. But the direction of flow of the earlier great ice sheet is more difficult to determine. Ice from the higher and more extensive plateau of the Cairngorm Mountains has apparently never overridden the Gaick plateau, though parts of Glen Feshie were undoubtedly covered by this flow from the E.N.E. No boulders of Cairngorm granite have been observed on the plateau. Mr. Cunningham Craig.

On the other hand, the ice flow moving north-eastward from the Moor of Rannoch and Beinn Alder does not seem to have encroached to any extent upon the western spurs of the Gaick plateau. Boulders of the hornblende granites and diorites from the Moor of Rannoch, though numerous in Glen Truim from Dalnaspidal northward, are rarely if ever observed in the Gaick Forest, except in the low ground about the Tromie. There is some evidence, however, of a movement eastward into Perthshire from the eastern limit of the Gaick Forest and from the plateau between Glen Truim and the Atholl Forest.

From this evidence it appears that the Gaick plateau, though it never reaches 3,000 feet in height, formed part of the ice-shed of the country during the great glaciation. The occurrence of great thicknesses of decomposed rock on the higher parts of the Gaick plateau favours this view. A thickness of 30 to 40 feet of rock, preserving the bedding and granite veins, and so disintegrated that it can be dug out like sand, is not uncommon. Had the surface been intensely glaciated, it is improbable that disintegration could have proceeded to such an extent since the glaciation, and hence this decomposition may be in part pre-glacial.

* *Quart. Journ. Geol. Soc.*, vol. xxxviii., p. 160.

Mr. Hinxman

Along the western margin of Sheet 64, Mr. Hinxman observed an important development of the lateral moraines of the Spey glacier on both sides of the valley in the Laggan district; and he also found evidence of a northward movement of the ice over the col from Dalwhinnie in Glen Truim into the Spey valley, and also from the Spey through Strath an Eilich to the head of Glen Banchor.

The lower spurs of the Monadhliath, which separate the three principal tributaries of the River Calder on its north bank, are each cut through, a short distance above the foot of each glen, by a deep and narrow dry gully. The distinct alignment of these gullies, coupled with their common E.N.E. trend and fall to the east, suggests their origin as the line of drainage of a series of small glacial lakes which occupied the upper portions of the valleys of the Allt a' Bhealaich, Allt Fionn-righe, and Allt a' Chaoruinn at a time when Glen Banchor, the valley into which all these glens debouch, was filled with ice.

The upper limits of the shrinking Glen Banchor glacier are well shown by the terraced moraines at the mouth of the Allt a' Chaoruinn glen, and on the hill sides east of Creag an Loin.

Numerous well-rounded erratic blocks of grey hornblende-biotite-granite occur throughout Upper Badenoch and Glen Truim. The source of these boulders may be looked for in the west, in the granite intrusions of the Ben Alder Forest and at the head of the Spey.

A wide stretch of alluvial sand and silt above the constriction of the Spey Valley at Glen Truim Castle indicates the extent of the former lake basin between Auchmore and Laggan Bridge.

The whole of this small area is under sheep, while most of it is grouse moor. Much of the hill ground above the limits of the valley glacier drift is bare and rugged, with shallow peaty soil in the hollows between the rocky eminences. On the west side of Glen Truim there are extensive stretches of drift covered ground, and these, together with the grassy lateral moraines and wide alluvial flats of Glen Banchor and the Spey, afford excellent grazing for sheep and cattle.

Mr. Wilson

During his re-examination of the Tay valley last season, Mr. Wilson obtained evidence pointing to the existence of a glacial lake in the valleys of the Tay and Tummel.

From the northern limit of the narrow "Pass of Birnam," northward to Pitlochry and Grantully, both sides of the Tay and Tummel valleys are occupied by a series of well-marked terraces which lie above the ordinary river alluvium and are almost entirely composed of soft glacial silt and sand with horizontal bedding. From the nature of their contents they could never have been deposited by the present river, but are clearly lake deposits.

For 1¾ miles the whole of the "Pass of Birnam," is filled with a large accumulation of coarse morainic detritus mixed with gravel in the form of hillocks of various size. These rise to 450 feet above sea level, or 286 feet above the solid rock there exposed

in the bed of the river. This deposit formed the barrier which held back the waters of the lake of Strath Tay and the lower Tummel valley. This sheet of water must have come into existence during the closing phases of the later glaciation. From the thickness of the more or less denuded terraces which remain, the period of time during which this silt was deposited must have been of considerable duration. Mr. Wilson made a number Mr. Wilson.

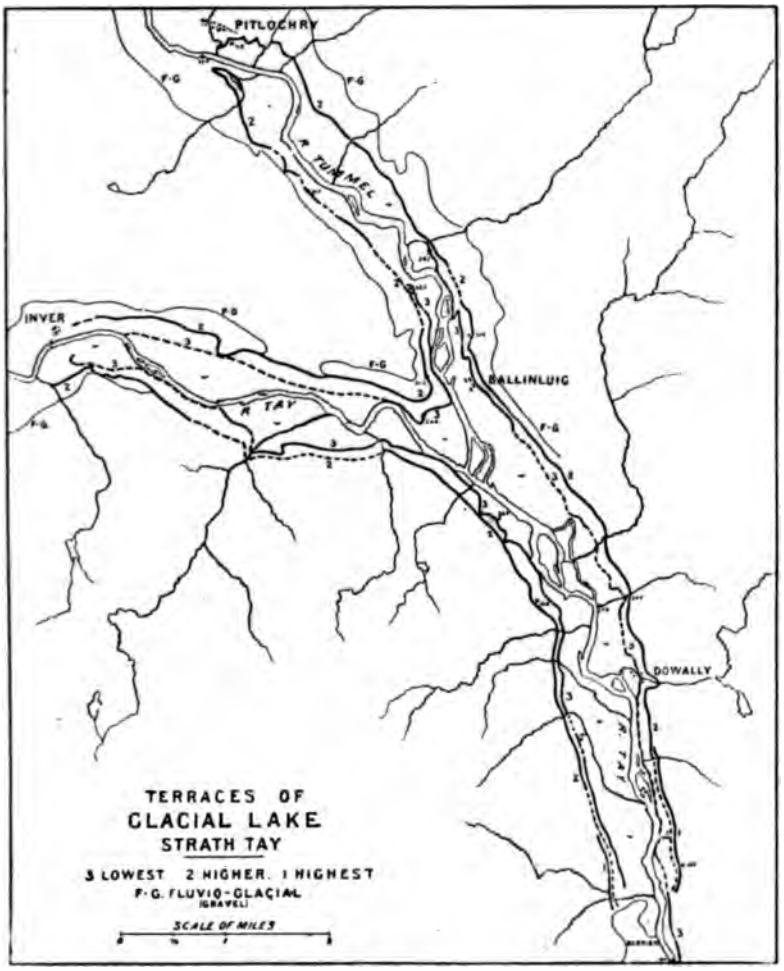

FIG. 4.

of observations with the Abney Level all over these lake terraces and found that, immediately to the north of the barrier at the Pass of Birnam, a terrace, 354 feet above sea level, extends up the Tay valley to Dalguise, a distance of two miles. This terrace at its lower limit ends abruptly on both sides against the moraine barrier. A fall in the level of the lake is indicated by a lower terrace at a height of 316 to 318 feet, which has been traced almost continuously on both sides of the Tay and Tummel valleys to Grantully and Pitlochry. A further fall in the level of the lake

Mr. Wilson. is recorded by the lowest terrace (269 feet) which has been followed northwards, in the Tummel valley to mid way between Logierait and Pitlochry, and in the Tay valley to near Grantully. During the period which has elapsed since the barrier was finally breached and the lake drained, the Tay has eroded the lower terrace and fragmentary portions only now remain. A careful examination of the sections exposed by the streams which intersect these terraces, together with the numerous levels taken all over them, suggests their lacustrine origin.

Immediately above these lake terraces there is a well marked deposit of fluvio-glacial gravels in the form of hillocks, kames, and sheets. They first appear a little to the south of Ballinluig and extend up both sides of the Tay valley to within a short distance of Aberfeldy, where they merge into the large moraines which stretch from the foot of Farragon Hill and down into the Edradynate valley. In a similiar manner these gravels occupy the Tummel valley and extend to the foot of the large terminal moraines which lie immediately to the north-west of Pitlochry. At several localities they are seen to lie upon the denuded edges of the upper lake terrace, while their upper limit, where not bounded by rock, rests upon stiff Boulder Clay.

The position occupied by these gravels, together with the general character of their materials, seems to indicate that during the period when the lake was gradually shrinking by the lowering of its barrier there was a temporary advance of the western and northern ice.

A very important fact in economic geology relating to the future water supply of this district is that the upper limit of these gravels is very clearly defined by a series of strong springs of good, potable water, particularly between Edradour and Delcapon in the Tummel valley.

4.—Rum, Eigg, and Part of Mull.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. George Barrow, Mr. Alfred Harker, F.R.S. } Geologists.

The geological formations and groups of rock entering into this district, are as follows, in descending order:—

vi. Post Glacial and Recent.
v. Glacial Deposits.
iv. Tertiary, chiefly Volcanic and Intrusive Igneous Rocks.
iii. Jurassic.
ii. Cambrian (detached masses in lines of crush).
i. Torridonian.

Isle of Rum.

Mr. Harker. The mapping of the Isle of Rum was begun during the past year by Mr. Harker, and engaged him through the field season. The total area of the island is about forty-two square miles and three-fourths of this has been completed. Excepting a small farm at Kinloch and a few isolated crofts in other places, there is no cultivation; the island being devoted partly to sheep, but

chiefly to deer. It divides roughly into a northern moorland tract, of which the highest points fall a little short of 1,000 feet, and a southern mountain tract with much more pronounced relief. Although the greatest altitude of this is only 2,659 feet, some of the peaks have bold outlines, and they are in general of naked rock. Mr. Harker.

TORRIDONIAN AND CRUSHED CAMBRIAN STRATA.

Torridonian strata make the country rock over the northern part of the island, and extend as a strip along the east coast. The relatively undisturbed portion of the formation, which covers the greater part of this area, has a general dip to W.N.W. at angles usually between 10° and 20°. It divides into two groups; the upper of felspathic sandstones with a more or less pronounced reddish colour, the lower principally of dark shales. The apparent thicknesses of these two groups, as observed, are about 9,000 feet and 1,400 feet respectively; but widespread signs of disturbance on a small scale forbid us to attach any precise value to these estimates. Close observation reveals numerous violent contortions in the sandstones and acute zigzag folds in the shales, where on a cursory view the appearance is that of a steady gentle inclination. Owing to the arrangement described, the upper or sandstone group occupies the greater part of the Torridonian area, the shales below occurring especially on the east side.

Disturbances on a larger scale and with more striking results are seen in two districts. The first is a small area in the north-western part of the island, named Monadh Dubh. Here a considerable overthrust fault, with a gentle inclination to N.W. has brought a cake of highly disturbed rocks, about one mile by two-thirds of a mile in extent, to rest on the ordinary sandstones. These latter show to the eye no special sign of disturbance. Immediately above the thrust-plane comes in most places a crush-band consisting largely of limestone, mingled with sandstone. The two rocks are brecciated and in part ground down together, but there are lenticles of limestone several yards in length. It is easily recognised as the Cambrian (Durness) Limestone, a rock which has not been found in place on the island. To this calcareous band, which is not many feet in thickness and not everywhere continuous, succeeds a greater thickness of crush-breccia or crush-conglomerate composed of red sandstone with only occasional lenticles of limestone. This passes up into a schistose rock, which seems to be essentially a mylonite of sandstone, but still contains a few pieces of limestone. The isolated occurrence of this patch of overthrust rocks, cut off to the north-west by the sea, precludes any further direct examination of their relations.

The second district of highly disturbed strata is more extensive. It is in the east-central, eastern, and south-eastern parts of the island, and consists of a belt of overthrust Torridonian bordering the mountain tract along this line. The mountains are built of Tertiary plutonic rocks, intruded not far from the overthrust—in this place a little above it. Farther

Mr. Harker. west the prolongation of the overthrust is lost, owing to the encroachment northward of the intrusive rocks. The thrust-surface itself is curved, and its inclination varies considerably. In the central part of the island the effect of the movement—neglecting minor overthrusts in advance of the main one—has been to bring the lower group (shales) to overlie the upper (sandstones). A prominent feature is the prevalence of crush-breccias, sometimes attaining a considerable thickness. Both sandstone and shale have contributed to these; and much of the breccia has probably been furnished by the transitional strata, which are alternations of sandstone and shale. In the strip of overthrust strata bordering the east coast, the relations are sometimes more complicated, and the disturbance seems to be more intense. This is especially the case on the slopes of Beinn nan Stac and Sgùrr nan Gillean. Along the whole of the belt the disturbed strata have suffered metamorphism, sometimes of a high degree, in consequence of the large Tertiary intrusions. A feature of special interest is the occurrence of lenticular masses and patches of gneiss, usually of acid composition, but partly also basic and of mingled (hybrid) nature. These are undoubtedly intruded in the Torridonian rocks, which are always highly metamorphosed at these localities; and various facts which cannot be detailed in this place, suggest that the gneisses belong to the Tertiary intrusions of the district. Their injection is clearly posterior to the great disturbances; but, exceptionally, the gneisses themselves have been crushed and brecciated, indicating (on the hypothesis suggested) a certain amount of movement in Tertiary times along the old lines.*

Isle of Eigg.

Mr. Barrow. During last season Mr. Barrow began the mapping of the Island of Eigg, which is made up partly of Jurassic sediments and partly of volcanic and intrusive igneous rocks of Tertiary age.

Jurassic.

Northern Part.—The northern part of the Island of Eigg presents an unusual structure. Though built up of beds which are approximately horizontal, more than half of these are sheets of igneous rock.

Dealing first with the sedimentary rocks, the youngest are of Oxfordian age, and the oldest met with during last season belong to the Great Estuarine series, locally representing the Great Oolite.

The Great Estuarine Series. (Great Oolite.)

(1) The lowest beds met with consist of dark shales containing comminuted shell limestones. These are so much split up with numerous intrusions of basaltic rock that it is impossible to

* See Harker "The Overthrust Torridonian Rocks of the Isle of Rum, and the Associated Gneisses." *Quart. Journ. Geol. Soc.*, 1903

ascertain definitely their thickness, which, however, must exceed a hundred feet. The basement beds of this group contain fish scales, and are probably on the same horizon as similar shales in Skye. They certainly overlie the Inferior Oolite. Mr. Barrow.

(2) The shales just referred to are overlaid by the Great Estuarine Sandstone which probably attains a thickness of some 200 feet, and is divided into three or four portions by partings of muddy sediment, which are thin and not always persistent. Comminuted shell bands also occur but are rare, and plant remains are fairly common near the base. The sandstone has long been famous for its huge concretions. The well-known musical sands noted by Hugh Miller are derived from the disintegration of this rock. The Great Estuarine Sandstone passes up into a limestone, from 10 to 12 feet thick, divided by a shaly parting containing layers of the well-known fibrous calcite. The comminuted shell bands in this series clearly represent the *Cyrena* Limestone of Skye.

(3) The limestone, overlying the Great Estuarine Sandstone, is succeeded by about 10 feet of shale, in turn overlaid by a calcareous grit which passes up into a cream coloured limestone, the whole being about 20 feet thick. Fossils are scarce except at the base of the grit, which latter presents many of the characters of beds that contain derivative forms, and care must be taken to make certain that the fossils belong strictly to this bed. In the higher calcareous bands in the shales the fossils that do occur are often comminuted, but there can be no doubt that they represent the *Paludina* Limestones of the Skye succession as worked out by Mr. Wedd. At the base of these shales the typical *Ostrea hebridica* beds occur, which seem to form a singularly persistent horizon in the Oolitic rocks of the Western Isles of Scotland. They are exposed in the little gorge east of Laig farm. Close to the Catholic Chapel, the lowest *Ostrea* Limestone has been quarried.

Above the cream-coloured limestone a gap appears in the sequence owing to igneous intrusions, and to the section being hidden by sand at Laig Farm.

OXFORDIAN.

On the other side of the gap, and on the south shore of Laig Bay there occurs a set of soft grey shales containing cordate Ammonites of undoubted Upper Oxford Clay age. These rocks are the youngest of the Jurassic succession met with in this region during last season.

Isle of Rum.

TERTIARY VOLCANIC, AND INTRUSIVE, IGNEOUS ROCKS.

Of the Tertiary igneous rocks, which occupy fully one half of the area of Rum, by far the greater part occur in the form of massive intrusions referable to the plutonic phase of activity. The preceding volcanic phase is represented in the western portion of the island by some patches of basaltic lavas, etc., Mr. Harker.

Mr. Harker.

partly resting on the Torridon Sandstone, and partly enveloped in granite. Elsewhere these lavas, which have doubtless had a very wide extension, have been stripped away in the progress of denudation. The final or "dyke phase" is represented by basic dykes and sheets, which traverse the plutonic rocks as well as the Torridonian strata; but, though these minor intrusions are numerous, their total bulk is insignificant in comparison with the large masses.

The plutonic rocks, which build the mountains of Rum and form also some of the lower hills, belong to three great groups—ultrabasic, basic, and acid. These were intruded in order as named, *i.e.*, in an order of decreasing basicity, and the three groups are fairly comparable as regards the scale on which they are developed. They correspond in the order of their intrusion, as they do generally in their petrographical characters, with the three groups of plutonic rocks distinguished in the central mountain district of Skye; but there are noticeable differences between the two areas. In particular, the ultrabasic group attains in Rum a much greater prominence than in the more northerly island, and presents an interesting variety of petrographical types. This is certainly the most distinctive feature of this special focus of igneous activity.

The ultrabasic rocks build a large part of the Rum mountains, including Askival, Allival, and Barkeval, and further form a tract of lower hills in the west-central part of the island. The area thus indicated is continuous, with a greatest extent of about 4½ miles. In addition, there are numerous small intrusions in the Torridonian tract to the north and north-west. Petrographically, the rocks present a considerable range of variety, especially in the large continuous area, which must be a complex formed by numerous injections. Olivine is usually a very abundant constituent, and ordinary varieties of peridotites and picrites generally prevail, at least on the lower ground. In Allival and Askival, however, these are associated with more felspathic types, the felspar being constantly anorthite. There are simple olivine-anorthite rocks, and others in which the pyroxenes, augite and enstatite, enter in various proportions. The several types alternate in parallel sheets, with a gentle inclination to the horizon; in addition to which there may be some banding on a smaller scale, and in places a parallel disposition of the component crystals. In other types, again, a rhombic pyroxene partly or wholly takes the place of olivine, giving a very beautiful enstatite-anorthite rock, a pure enstatite-rock, and other varieties in which augite and olivine also take part. A considerable area of rocks of these kinds occupies the hills to the north of Harris and near Loch an Dornabac, and here they are seen to break through the peridotites, giving rise along the junction to a broad zone of intrusion-breccia.

The gabbros which constitute the second group of plutonic intrusions, are probably in great force in the southerly mountains, which have not yet been surveyed. On the ground mapped during the past season those rocks occur chiefly as a massive

irregular sheet or laccolite (probably continuous with the main body), intruded at the base of the preceding group along the north-easterly and easterly slopes of the mountain tract. There is less petrographical variety than in the ultrabasic group, and the banding, though often evident, is less pronounced. The posteriority of the gabbro is clearly shown in many places. In addition to the principal area, there are numerous smaller masses breaking through the ultrabasic rocks and the Torridonian strata. Mr. Harker.

The third (acid) group of plutonic rocks is developed especially in the western part of Rum, where Orval and the neighbouring hills are formed by a large mass of granite. The rock is usually hornblendic, the hornblende being in part derivative after augite, and, like other British Tertiary granites, it has a strong tendency to micrographic structures. The acid gneisses of the island, which we have proposed to assign to the Tertiary suite of intrusions, present very similar characters, and on Beinn a' Bhàrr-shaibh there is a patch of gneiss, about a quarter mile long, enclosed in the granite with no sharp line of demarcation.

Intruded in the belt of overthrust Torridonian, and below the gabbro, there occurs in several places a conspicuously porphyritic quartz-felsite, with fine-textured dark ground-mass and constant flow-structure. On Meall Breac and elsewhere it is often crowded with *debris* of other rocks, especially of gabbro, from blocks many feet in length down to microscopic fragments. The felsite seems to be of later intrusion than the granite, but its precise position in the suite of associated rocks remains to be determined.

The minor intrusions in the form of dykes and sheets are of later date than the plutonic rocks, and they are all of basic composition. A number of strong sills intercalated in the basaltic lavas of Fionn Chrò belong doubtless to the group so largely developed in Skye and elsewhere. Basalt dykes of small or moderate dimensions intersect the plutonic rocks of the mountain tract, but are much more numerous in the Torridonian area. In their varying direction they show a very decided tendency to a radiate arrangement with reference to the mountain centre, *i.e.*, the south-central part of the island. Thus the prevalent bearing in the north-western area is N.N.W., in the north-central N., in the north-eastern N.N.E. As we pass southward in the eastern part of the island, the bearing changes to E.N.E., E., E.S.E., and S.E. To this radiate disposition there are many exceptions, and the types doubtless belong to more than one group, intruded at different epochs. In many places there are dykes running at right angles to the dominant radial set. In addition to the dykes, there are in the Torridonian tract numerous sheet formed intrusions, either following more or less closely the bedding of the strata or curving irregularly and rapidly swelling out and tapering away. A prominent example occurs near Kilmory. Some of these sheets are perhaps to be correlated with the more regular sills in the lava group, but others are of later date, and intersect the basalt dykes.

Island of Eigg.

TERTIARY VOLCANIC ROCKS.

Mr. Barrow. The igneous rocks of Tertiary age are divided into two groups by the Great Estuarine Sandstone. The upper group consists of a mass of decomposed basic igneous rock built up of continuous sheets with no visible ash or sedimentary material between them. Whether these sheets are sills as maintained by Hay Cunningham or true lava flows actually poured out at the surface, has not been proved by the evidence in the northern part of the island. At the base of the sheets are two specially interesting rocks. The lower is an olivine-dolerite, often 100 feet in thickness and rarely columnar in the northern portion of this area but usually so further south. Its base in the gorge east of Laig Farm is well exposed where its intrusive nature is clearly seen. The higher band is described by Mr. Harker as a mugearite and formerly by Sir A. Geikie as anamesite. A peculiar feature of the mugearite is its more or less persistent vesicular character. Moreover, the cavities are almost always elongated, are empty and have sharply defined walls. Now the olivine-dolerite below displays in a very perfect form the red top that is so often claimed as evidence of a land surface, but as the rock is intrusive this feature must be due to some other cause. The evidence on the ground makes it clear that the overlying intrusion, which is often crowded with gas cavities, acted as a local fumarole, and the red band is probably due to local fumarole action. Each successive intrusion seems to have introduced corrosive gases into the rocks, and it is an invariable rule that the oldest sheets are the most decomposed.

The lower group are evidently intrusive. The lowest member is a sill, more than 50 feet thick, composed of markedly basic material. Higher up is a markedly acid rock containing phenocrysts of quartz, which in one place reaches a thickness of at least 100 feet. It forms the foot of the cliff at the extreme north of the island, where it displays a well marked columnar structure.

The shales in their upper part are pierced by a number of thin dark sills, rarely more than ten feet thick, composed of olivine dolerite and often possessing columnar structure.

The closing phase of volcanic activity is marked by a great number of narrow dykes, which in some places give rise to small sills; an excellent example of which occurs in the mass of quartz-porphyry at the north end of the island. The dykes are fresh and as a rule fine in grain, though occasionally a small dyke is met with containing visible crystals of olivine, augite and felspar. These dykes always occur in small cracks which can often be proved to be lines of fault. As we approach one of these, the amygdules in the basic sheets, usually filled with calcite, invariably increase both in size and number. It is quite clear, therefore, that these amygdules cannot be taken as conclusive evidence that the rock was originally vesicular, still less that it was a lava flow.

MULL.

Mr. Harker.

In order to complete sheet 36, it was necessary to map a small portion of the south coast of Mull, including the headland named Malcolm's Point, to the west of Carsaig Bay. This was done by Mr. Harker. The cliffs here belong to the Tertiary basaltic group, and to the lower portion of it, the Cretaceous sandstones emerging from below sea-level only a little to the east, towards Carsaig. The basaltic lavas are mostly amygdaloidal and not of a very durable nature, but at numerous horizons are intercalated strong intrusive sills of dolerite. These become more numerous towards the upper part of the section, where the cliffs become accordingly more precipitous. Interposed among the basalts, near the base of the group, is a basaltic tuff, associated with which, and passing into it, is a conglomerate of rounded flint pebbles. This conglomerate, with a maximum thickness of about fifteen feet, is of quite local occurrence, and is doubtless a river gravel belonging to an early epoch in the volcanic period.

ISLE OF RUM.

PLEISTOCENE.

Glacial.

The glacial geology of Rum has been only very partially worked out, and the evidence seems to be not very complete. The fact that foreign boulders are found up to high altitudes, though sparingly and in diminishing numbers, may be taken to imply that the whole island was probably over-ridden by the Scottish ice-sheet. But though the ground reaches no lofty eminence, the relief is, at least in the southern half, of a bold type; and the trend of the striae shews that the movement of the ice was partly controlled by the more marked features of the land surface. On the more open ground the direction was towards W. N. W. There are abundant signs of a minor local glaciation succeeding the principal invasion. Thus, along the south side of Kinloch Glen, the main set of striae, directed westward, is crossed by a second set, pointing northward, i.e., from the principal high ground. In some other places indications of movement down a valley may point to glaciers of late date; but it is not always possible to discriminate the two sets of striae.

Drift accumulations do not in general attain any great development in Rum. Continuous deposits are usually almost confined to the floors of the main valleys. In Glen Harris and Glen Duibhal, however, on the west side of the island the drift is in greater force, and reaches a notable thickness.

ISLAND OF EIGG.

Mr. Barrow.

Glacial.—A number of boulders clearly derived from the mainland occur on the north and north-east shores of Eigg, but so far no typical boulder clay has been met with. Erratics are locally abundant on the higher ground in the central part of the

Mr. Barrow island and often occur in lines; each composed of one kind of rock, either quartzose Moine-gneiss or pegmatite. The ice streamed over the high cliffs of Cleadale, carrying boulders of pegmatite with it and eroding shallow hollows, which have been proved by draining to be true rock-basins.

Isle of Rum.

POST GLACIAL AND RECENT.

Mr. Harker. Although the rivers of Rum are necessarily of small volume, there are considerable gravel flats in the glens of Kilmory and Kinloch. Raised beaches are found on the sheltered parts of the coast. A twenty-feet beach makes some spread at Kilmory (where there is a well-preserved raised bar) and other places, while higher beaches occur at Harris and, in a fragmentary state, elsewhere. The peat, which covers much of the moorland ground, does not attain any considerable thickness.

It is worthy of note that during recent years the drainage system of the island has been artificially modified, as part of a scheme for improving the fishing in the Kinloch River. A portion of the drainage from neighbouring valleys has been diverted into Kinloch Glen. This work, begun and abandoned many years ago by the late Marquis of Salisbury, has now been carried out by the present proprietor, Sir George Bullough. It results that the Kilmory River, robbed of a part of its water, is no longer in proportion to its valley and to the gravel flat through which it meanders; while the volume of the Kinloch River is notably augmented. It will be of interest in the future to note the process, already perceptible in places, of adaptation to the changed conditions.

Island of Eigg.

RECENT.

Mr. Barrow. The movements that have taken place in Eigg in comparatively recent times are well shown by the phenomena associated with the alluvial flat about Laig Farm which marks the site of an old lake.

The sequence of events is briefly as follows:—

1. The island stood at a much higher level, during which period a deep valley was eroded by the two streams that now flow down into Laig Bay. The valley was carved out of the sedimentary material and extended far into the area now covered by the sea.

2. The land sank some hundreds of feet and the two streams discharged their sediment into the old valley; the sand being derived from the speckled black and white detritus of the olivine dolerite sheets.

3. The ice that streamed across Eigg dug out this incoherent material under the inland cliff, heaping it up close to the sea. The land at this period must have been about 100 feet below its present level, for there is clear evidence of the 100 feet beach on the west side of Cleadale.

4. The land subsequently rose and a fresh water lake was formed owing to the bar of heaped up material already mentioned; the latter being slowly cut through by the two streams till eventually the lake was drained. Mr. Barrow:

A curious confirmation of the fact that a valley was cut in the softer rock far beyond the present limits of Eigg is afforded by the fact that this filled up valley has been selected as the only part of the sea floor where the telegraph cables would be safe from injury during storms. They repose far out to sea on the sand filling the old valley.

ECONOMICS.

As the rainfall in Eigg is less than that in Skye the soil is not nearly so much washed away, and the upland forms rich grazing ground owing to the fertility of the material produced by the decomposition of the dolerite. The Cleadale and Kildonan areas are cultivated by the crofters where the land is comparatively flat and fertile. A practically inexhaustible supply of road metal exists in the island, but as there is no harbour, it is not available for economic purposes on the mainland.

Peat grows on certain flat, almost water-logged, surfaces and is of excellent quality. There seems a sufficient supply to last for some years.

5. REVISION OF CABONIFEROUS AREAS:

A.—MIDLOTHIAN, PART OF WEST AND EAST LOTHIAN AND PEEBLES-SHIRE.

Dr. B. N. Peach, F.R.S.—District Geologist.

Mr. L. W. Hinxman, B.A.
Mr. J. S. Grant Wilson
Mr. E. H. Cunningham Craig, B.A. } Geologists.

When the Lothians were first mapped by the Geological Survey, the oil shales were not known to be of commercial value. After the development of the field was begun, the revision of the area was undertaken, first by Sir A. Geikie, and subsequently by Mr. H. M. Cadell, who, during his connection with the Survey, re-mapped the whole oil-shale field west of Edinburgh, and, since his resignation, has kindly kept the information on the six-inch sheets up to date. In the course of his revision, Mr. Wilson has confirmed the conclusions arrived at by Mr. Cadell regarding the structure of the oil shale field. Mr. Wilson.

The greatest addition to our present knowledge was supplied by bores recently put down in the area lying between Broxburn, Pumpherston, and the River Almond, whereby the outcrops have been traced, of the Dunnet, the Pumpherston, and the Barracks oil shales and the Burdiehouse Limestone throughout this hitherto little known district.

Mr. Wilson. Some doubt still remains as to the exact horizon of a shale supposed to be the Dunnet in the Philipston and Lir gow Fields. Mr. Wilson is of opinion that it is not the Du shale, but an oil shale locally known as the "grey shale," lies between the Broxburn and Dunnet seams.

It has been observed that in this region all the shales, very few exceptions, deteriorate both in the quantity and qu of their oil-yield as they are followed downwards. Mr. W has obtained the following evidence, which seems to favou opinion that this deterioration is in some manner due to depth of the seams below the surface.

In No. 1 mine, Philipston, which is sunk in the Brox seam, the shale, from its outcrop down to 30 fathoms ver depth, gave a yield of 25 to 26 gallons of crude oil per From this point downwards the return gradually became till, at a depth of 70 fathoms, it had fallen to 11·3 gallons per The lithological character of the shale likewise changed became more dense, lighter in colour, and more distinctly rib

At No. 5 mine, in the same field, the Broxburn shale a outcrop yielded 30 gallons per ton, 25 gallons at 100 fathoms, then its yield rapidly fell till, at 150 fathoms, it amou to 12 gallons of crude oil per ton. In this mine the bo leaf of the seam wrought is a strong, "curly" shale, and conti to be so down to 100 fathoms. At this depth, and coinci with its decreasing yield of oil, it gradually becomes so n broken up that it practically passes into what coal miners "dross" that would pass through the meshes of an inch a-half sieve. These small pieces are thinly coated with a b lustrous substance, which, on analysis, proves to be albertite. large mass of this mineral was lately found in the shal this mine.

The above question has also been investigated by Mr. Ge F. McKillop, chemist to the Broxburn Oil Company, an finds that any oil shale, as it increases in depth, deteriorates in its yield of oil and in the quality of the oil produced. denser and deeper shales have less hydrogen and also less car and the result of this deficiency in hydrogen is that the sh on distillation, have a tendency to form denser carbon compo of the "olefine" and "acetylene" series, and also compoun the "napthalene" and "benzene" series. The crude oil is specifically heavier than that obtained from the same sea higher levels. The crude oil, on the first distillation of the d shales to dryness, leaves a much larger deposit of carbon the oil from a higher level. From the consideration of t facts it would appear that, in the basins into which those sh have been thrown by plication and faulting, now separate denudation, there has been a slow process of distillation goin whereby the higher parts of the seams have been enri at the expense of their more deep-lying portions. An important fact also leading to this inference is that, no m how the yield of crude oil varies in the different part any shale, the amount of ammonia remains constant.

Mr. Wilson mapped out a band of massive limestone in the area south of Linlithgow that probably represents the lowest of the Abden limestones in Fife and one of the Longcraig group of the Dunbar shore. Mr. Wilson.

PLEISTOCENE.

Glacial and Post Glacial.

Mr. Wilson found that the boundary lines for the Boulder Clay and glacial gravels require only slight modification; he mapped considerable areas of peat and alluvium, including the glacial lake of Winchburgh, the boundaries of which had not been defined, and he further traced the limits of the 100 feet and the 50 feet raised beaches.

ECONOMIC GEOLOGY AND WATER SUPPLY.

Brick-making.—The brick-fields at Blackness and Lampinsdub have been abandoned on account of the lack of railway communication. These are now replaced by three large brick works at Winchburgh, Camps and Ecclesmachan equipped with the most modern machinery and continuous burning Hoffman kilns. The material used at the first two localities is Boulder Clay and "blaes" which are excavated together in about equal proportions. The large stones in the clay are thrown aside and the mixed material is ground in a pug mill and then passed through brick-making machines. At Camps the output per day averages 20,000 bricks. The material used at the works at Ecclesmachan, which are now idle, was Boulder Clay and the black shale on top of the Binny sandstone. At Camps the shale lies immediately above the Burdiehouse limestone and at Winchburgh the fakey blaes (sandy shale) is in close proximity to the Dunnet shale. The bricks produced at both works are of good quality.

Freestone.—The extensive quarries at Ecclesmachan in the Binny sandstone are now abandoned, but a large quarry has been opened in the same bed of rock to the north-east of Winchburgh on the Forth Bridge Railway which produced excellent building material. Another equally good quarry is situated at Pardovan, probably on the Kingscavil sandstone, the horizon of which is a little above the "two feet" coal.

Water Supply.—The water supply all over this part of the country is very deficient. The streams as the result of the oil and mining industry are all more or less polluted. That the Calciferous Sandstone series as here developed does not hold much water is proved by the small amount of pumping required at most of the oil-shale pits and mines. Very few wells are now used and the district is almost entirely served by water mains which draw their supply from the hills to the south, outside the present area.

Mr. Wilson wishes to take this opportunity of thanking the mining engineers at the different shale works visited by him, who have kindly placed their entire information at his disposal. He has examined a large number of mining plans and procured

Mr. Wilson. copies of numerous vertical and horizontal sections and also of the journals of several important bores made with the diamond drill.

Mr. Hinxman. Mr. Hinxman examined the Carboniferous Limestone area that occupies the south and south-eastern part of the Midlothian Basin between Gorebridge, Howgate, and Penicuick.

Owing to the thick covering of drift over most of this ground, it has not been found possible to separate the limestones of the lower group throughout the area. At certain points where new evidence is available, as between Middleton and Esperston, the lines on the present map have been slightly modified, and to the south of Mount Lothian the limestones have been differentiated for a short distance.

There is evidence that the limestones become much thicker in the southern part of the area, and as this may be due to the coming together of two or more bands and consequent elimination of the intervening strata, it does not appear advisable to draw, what must be purely conjectural lines, for the outcrop of the bands through drift covered country. It is perhaps safer to indicate by one colour the belt occupied by the lower group of limestones as a whole, separating the different bands where they can be traced by a deeper shade of the same. Most of the quarries in the district are now closed, and the limestone is now only wrought at Middleton and Esperston limeworks, the former in No. 1, the latter in Nos. 2 and 3 limestones. The stone is of good quality and is used entirely for building and agricultural purposes.

Plant-remains have been collected by Mr. Tait from the shales and sandstones that immediately overlie the highest (No. 6) Limestone to the N.E. of Penicuick. These have been submitted to Mr. Kidston who has identified among them, Lower Carboniferous species of *Lepidodendron* and *Astero-calamites;* and also a *Sphenopteris* of Lower Carboniferous type. He considers the fossil evidence conclusive as to the Lower Carboniferous age of the strata containg these plant remains.

In the North Esk River at Esk Mill, and in the burns which fall into the Esk at Auchindinny House, the sections show that the upper limestone is succeeded by 120 to 150 feet of dark shales with ironstone nodules and faky sandstone, from which the plant remains referred to above were obtained. Above these come a series of thick bedded, yellow, grey, and reddish gritty sandstones with occasional intercalations of shale. From one of these intercalated bands of dark shale with ironstone nodules, quarter of a mile east of Auchindinny, Mr. Tait has obtained *Calamites* of Lower Carboniferous type.

Drift.—A wide sheet of sand and gravel covers most of the lower ground that extends northwards from the base of the Moorfoot Hills. The gravel seems everywhere to be underlain by Boulder Clay which is exposed by denudation in the valleys and stream sections. The plateaux-like character of the deposit

is well marked between Gorebridge and Borthwick where the flat summits of the undulating plain rise to a uniform height of between 700 and 800 feet. Mr. Hinxman.

In the western district, between Penicuick and Temple, the gravels are more irregularly arranged, and often form isolated mounds and kamiform ridges. An examination of the gravel points to its having been derived from the west. A large proportion of the pebbles is composed of volcanic and basic igneous rocks, similar to those of the Pentland Hills and the country to the west of that range.

The Pentland and Braid Hills District.—During the revision of Sheet 32, a large part of the Pentland Hills has been re-examined. In this area the structure has been found remarkably difficult to elucidate. As is well known, a series of conglomerates and sandstones of Lower Old Red Sandstone age rest on upturned Silurian strata, which are succeeded by lava flows of basic andesite, felsite, and andesite of less basic composition, while intercalations of ashes, conglomerate, and sandstone occur here and there. It has also been pointed out that the lowest conglomerates are formed of greywacke, radiolarian chert, and acid igneous rocks of earlier date, while at higher horizons, even before the first volcanic rocks are reached, pebbles of andesite appear. It is now found that the lowest conglomerate is repeated more than once amidst what was formerly believed to be a regular upward succession from north-west to south-east. The mapping of faults which repeat the succession or part of it has entailed the careful re-survey of much of the ground. Mr. Cunningham Craig.

Of the volcanic necks represented on the map, it is found that only one or two small ones can be proved to be actual vents, the larger ones, such as those on Torduff Hill and the Braid Hills, consist almost entirely of lava flows chiefly acid in composition.

The area is not yet fully examined, and many parts of the structure may remain obscure owing to the paucity of exposures and the lack of clear sections.

Arthur's Seat and the City of Edinburgh.—The chief point of interest in the revision of Arthur's Seat is the discovery of a mass of agglomerate extending from near the "Cat Nick" on Salisbury Crags almost to the old "Camstone Quarry" on the south side of the Hunter's Bog. This mass probably represents an independent volcanic vent or neck from that which forms the "Lion's Head" and the "Lion's Haunch." The agglomerate is made up chiefly of blocks of olivine-basalt set in a finer matrix of the same material, together with a certain amount of sand. The matrix has been much hardened, suggesting the idea that it has been altered by the intrusion of the sheet of dolerite of Salisbury Crags. An attempt has been made to map out in detail the material that now fills the larger vent forming the main mass of Arthur's Seat, which, as is well-known, is partly made up of agglomerate, lavas, and various intrusive rocks. Dr. Peach.

B.—Prestonpans to Cockburnspath.

Mr. C. T. Clough, M.A., District Geologist.

Mr. G. Barrow
Dr. C. B. Crampton } Geologists.
Mr. E. B. Bailey, B.A.

The revision of the Carboniferous Rocks in one-inch Sheets 33 and 34, was begun last autumn. These belong partly to the Calciferous Sandstone series and partly to that portion of the Carboniferous Limestone series of Scotland * which comes below the Edge Coals of Mid Lothian. To elucidate the geological structure it was found necessary to examine some portions of the Upper Old Red Sandstone.

Most of the district is deeply covered with superficial deposits which greatly obscure the solid geology.

Mr. Clough. The narrow tract of Carboniferous rocks between Oldhamstocks and the eastern outskirts of Dunbar is bordered on the west by a great line of disturbance, generally striking N.N.W., and the strata near this line are also almost parallel to it and inclined at high angles. In Ogle Burn and Broadwood Burn, we find, mixed with the coarse Old Red Sandstone conglomerate on the west side of the line, thin strips of Silurian greywacke and shale, striking N.N.W., almost at right angles to the usual strike in the Lammermuirs. Near Broxmouth, the disturbance is represented by several lines of fracture and contortion. The beds are frequently reversed, and the sandstones and shales below the Skateraw middle limestone are thrown into small folds, some with both limbs inclining W., and crossed by several small thrusts dipping W. at low angles. On the shore N.N.W. of Broxmouth, the beds belonging to the Carboniferous Limestone series, the Cementstone division, and the Upper Old Red Sandstone, are generally reversed, with a steep westerly inclination, and, some distance west of the most disturbed part, the Old Red Sandstone is twisted into a sharp double fold in which the axial planes strike nearly N. and S., and the western limb of the anticline is steeper than the eastern.

These phenomena near Broxmouth indicate that in this locality the beds west of some of the lines of fracture, have been to some extent thrust over the higher beds on the east.

It may also be said that on the coast east of Skateraw and nearly a mile and a half E.N.E. of the line of disturbance referred to, the Skateraw middle limestone is often folded into small anticlines and synclines, with axial planes striking about N.N.W. and generally either vertical or inclining west. In one place, also, a little thrust is seen, dipping west at about 20°.

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* Mr. Gunn has shown ("Correlation of the Carboniferous Rocks of England and Scotland," *Geol. Mag.* 1898, Dec. iv. vol. v. p. 342) that the Carboniferous Limestone series of the North of England includes many beds which are below the Carboniferous Limestone series of Scotland.

CALCIFEROUS SANDSTONE SERIES.

Dunbar and Cockburnspath District.—At Cove harbour, Linkhead, Thornton, and in Dunglass dean there are thin impure crinoidal marine limestones which must be far below the line which has been taken as the base of the Carboniferous Limestone series of Scotland. There are two limestones at Cove harbour, and it seems probable, on stratigraphical grounds, that the lower of these is on the horizon of the Linkhead limestone, but they differ from each other in their fossil contents. Mr. Clough

A little below the lower of the two limestones at Cove comes the massive, yellow or red, sandstone of Heathery Heugh with some thin partings of purple or pale grey clay; the thickness being about 160 feet. Below this comes a series of dark grey shales, thin sandstones, fireclays and thin coals (Scremerston division), none of the latter being more than ten or eleven inches thick. These coal-bearing beds are all nearly vertical, being near the north side of a large fault,—not noticed in the original survey,—which on its south side has beds belonging to the Cementstone division. On the foreshore west of, and overlying, the Upper Old Red Sandstone, there are shales and cementstones, from 50 to 60 feet thick, followed by a fine-grained, pale grey sandstone, about 150 feet thick, forming the Horse Road rock. This sandstone is regarded as part of the Cementstone division,* for on examining the cliffs, we find coming on above it about 300 feet of greyish green shales, thin sandstones, and cementstones.

It is possible that the fault just referred to, may have thrown out from the coast section, not only beds belonging to the Cementstone and Scremerston divisions, but also others on the horizon of the Fell sandstones, and lavas and tuffs representing the volcanic series of Dunbar and North Berwick. There is near Branxton a considerable thickness of deep red, probably stained, sandstones, and the lower of these may be on the horizon of the Fell Sandstones. In considering the possibility of finding workable coals belonging to the Scremerston division in some inland locality on the north side of the fault, it has to be noted, that in Dunglass dean a smaller thickness of coal-bearing beds has been preserved than on the shore.

Near Oldhamstocks, on the south side of the fault above referred to, there is, besides a basic intrusive rock, rich in olivine, a considerable thickness of bedded ash, and some highly vesicular igneous rocks, which are probably lava flows, and it seems likely that these belong to the Cementstone division, and are nearly on the same horizon as the volcanic rocks of Dunbar. Ashy sandstones and vesicular igneous rocks, probably representing lava-flows, are seen in the Cementstone division on the shore

*The Calciferous Sandstone series of the Borders is often separable into the following divisions, beginning at the top:—

1. Calciferous Division, with marine limestones.
2. Scremerston, or Carbonaceous, Division.
3. Fell Sandstones.
4. Cementstone Division.

Mr. Clough. nearly a mile east of Dunbar, and ash, probably in the same division, occurs in the railway cutting near Broxmouth.

A little above the limestones of Cove harbour there comes a thick, massive, rather coarse, yellow or red, sandstone, 60 or 80 feet thick, and then a greyish green or purple clay with a thin oil shale, about a foot thick, at the top. This shale is well seen north of the harbour, and also near the mouth of Dunglass dean, the intermediate shore section being occupied by higher beds. This shale is the only oil shale known in the district, and it is probably on the horizon of one of the workable shales of the Lothians, but the beds above and below it are very false-bedded, and it has not been seen in places where we expected to find it, near the foot of Bilsdean and further north-west.

A coal, about 10 inches thick, occurs a little above the limestone at Linkhead and was formerly worked along the outcrop for local use. It seems probable that this coal improves in quality inland, or else that in some places it is accompanied by another coal of more value, for on the shore about a quarter of a mile south east of Linkhead there are the mouths of two old levels which have been driven in a south-west direction, and in a field a considerable distance from them, and on the south-west side of the railway line, there appears to have been shafts which were connected with these levels. These old workings are said to have ceased about a hundred years ago. The coal worked is reported to be 4 feet thick, but no trustworthy information about it can be obtained.

In the Broxmouth railway cutting there is about 150 feet of white and red sandstone at the top of the Calciferous Sandstone series. On the coast north of Thorntonloch, the lowest limestone of the Carboniferous Limestone series is found on the north side of a fault hading north, but the sandstone on the south side is like that referred to in the railway cutting, and it is not probable that many beds are faulted out.

Mr. Barrow. *North Berwick District.*—A striking feature of this area is the great amount of igneous material present, mainly of volcanic character, but partly in the form of plugs. The clastic rocks vary much in composition, though in all but the higher divisions fragmental igneous material is present, and one important zone consists mainly of true volcanic ash. The divisions of the clastic rocks are as follows in ascending order:—

GROUP I.

(*a.*) The lowest rocks consist of soft red and white sandstone with a large amount of hard red sandy marl, and softer red and pink marls, which are seen on the coast north of the Tyne mouth.

(*b.*) The lumpy "Agglomerate" is associated with part of the last group on the shore due east of Whitekirk, and forms extensive scars which weather into large rounded masses. The matrix is a red sandy marl or a fine pink marl, the latter with distinct bedding, while in the former,—the more common type,—the bedding is often difficult to determine. Numerous fragments of marl and marly sandstone occur in it, as well as rarer pieces of igneous material. The rock is usually so soft that it has not been ascertained if fragments of the typical ash occur in it or not. At the top of this zone there is a hard white sandstone which often lies in eroded hollows.

(*e.*) Soft red sandstone and red and salmon-coloured marls, often showing well-marked parallel bedding, and forming parallel scars on the coast. This zone contains much fewer derived fragments than (*d*), and less recognisable igneous material. The weathering of the sandstones, however, suggests that they are somewhat ashy. Mr. Barrow

(*d.*) The Green Ash is typically developed on the cliffs and shore for some distance east of North Berwick. Where the ash is fairly pure, it is cemented by lime set free by decomposition of the fragments of basic rock (often a vesicular glass originally) of which the ash is composed, and there is a development of chlorite that colours the rock green. At Seacliff a homogeneous mass of this ash was pierced for 170 feet without proving either the top or bottom. In many cases, however, the green ash contains a vast number of fragments of all sizes. Most of the harder material is well rounded, but large angular fragments of green ash and sedimentary material occur locally. At the base of this zone a bed of limestone often occurs, and has been quarried in several localities, as, for instance, in the Rhodes quarry near North Berwick; but it does not occur on the coast, though it may be represented by a few calcareous bands.

Immediately above the green ash are some mottled red and green ashy beds, associated with soft green and dark mudstones, which are accompanied with thin bands of hard, often cherty, limestone, but the whole group is so soft that little of it is seen on the coast. A portion of these beds is seen to the west of North Berwick Bay, and a boring in the town proved a considerable number of the thin calcareous bands.

(*e.*) Next in order comes a series of red sandstones and pink and red marls, seen in North Berwick Bay and east of Kirkness, which are often agglomeratic, but the bulk of the irregularly shaped fragments are of marl or sandstone. Many of the harder fragments are well rounded. Microscopic sections show that the sandstone contains fragments of ash originally identical with the material of the green ash, but stained red. A feature of these red sandstones is the number of grains of fresh microcline which they contain; indeed it seems to occur in all the red sandstones, but is specially abundant at this horizon. At the top of these red sandstones and marls most of the volcanic sheets occur, though it has not been proved that they keep exactly to one horizon.

(*f.*) At the west end of the sandy shore east of North Berwick, the highest of the volcanic sheets is surmounted by some 30 feet of ash, associated with fine marl, and apparently baked by the igneous rock. The ash is remarkable for the rapid change in colour of the various bands composing it.

GROUP II.

(*g.*) Above the ashes last referred to, is a yellow agglomerate, or breccia, of variable composition, which appears to be the lowest bed that contains well rounded fragments of the undoubted volcanic sheets. It contains also decomposed fragments identical with the decomposed trachyte, the intrusive nature of which, in many localities, is indisputable. These suggest the presence of an important break.

(*h.*) Next in order come some dark shales with thin beds of red weathering impure ironstone, which are very persistent and form a series of minute but rigidly parallel scars. They occur on the west side of the woods that stretch from Dirleton to the coast.

(*i.*) Calcareous sandstones and marls, which are separated from zone (*h*) by a fault which may have a large downthrow. Similar rocks occupy the shore in the area north of Gullane for a considerable distance. They often appear ashy, but when baked so that the fragments in them are preserved, it is seen that the latter, whether angular or rounded, are not as a rule of igneous origin. Some bands do contain igneous fragments, but it is possible that these have been supplied by ordinary denudation. Fragments of the volcanic sheets often occur in the sandstones and purple marls. Some black shale and thin ironstones occur in the middle of the long outcrop of these calcareous sandstones, and part of the shale is a true oil shale. The latter underlies calcareous sandstone, and may possibly be a bed in zone (*h*), though in the main outcrop of this zone no bituminous shale is seen.

The igneous rocks of the district, excluding the ash beds, are divisible into three groups, as follows :—

1. The oldest group, consisting of volcanic sheets.
2. The trachytic rocks.
3. The black basaltic rocks, more recent than either of the above.

1. The volcanic sheets are basic or intermediate rocks. The most basic often contain large augite crystals enveloping grains of olivine. Porphyritic felspars are present in all but one or two varieties, and at times are so abundant as to give a character to the rock. A peculiar feature of some of the sheets is the occurrence of much felspar and a great deal of olivine but very little augite. There is one type of rock, which forms the mid band of the North Berwick breakwater and may be called the Congleton rock, which contains few, and often no, porphyritic crystals and is the least basic of the series. It can be easily identified as it shows unusual characters both in the field and under the microscope. The top of it is always slaggy and at times exceptionally so.

2. *The trachytes.*—An excellent description of some of the trachytes has already been given by Dr. Hatch.* An examination of specially fresh material suggests that green (soda) augite is a more persistent component of these rocks than was formerly supposed. All these rocks occur as bosses, or as intrusive sheets given off from them. As a rule the sheets do not extend far from the parent stock.

3. The black weathering basaltic rocks have not yet been seen to intrude into rocks of group (2) though they pierce rocks far above these. They usually occur in the form of sheets or sills which have been fed from a great number of separate bosses, fine examples of which are seen in some of the islands off the North Berwick coast. In composition they range from olivine-dolerite, or basalt, with very little felspar to a dolerite with no olivine and an excess of felspar.

Haddington and Gifford District.—At Yester, where beds of the Calciferous Sandstone series come against the Upper Old Red Sandstone, there is no sign of the Cement-stones elsewhere met with at the base of the Carboniferous system, and probably they have been cut out by the Lammermuir fault. The beds next the fault on the N.W. side, are ashes and ashy sandstones, which are, in all probability, on the horizon of the Garlton volcanic rocks. Above the ashes comes a series of sandstones and clays, mostly white but occasionally red, followed by a thick series of sand-stones and clays with thin coals and oil shales, well exposed in the Sandersdean Burn. Here, about midway in the series, a thin encrinital limestone occurs and is perhaps on the same horizon as a similar bed at Inglisfield.

* "The Lower Carboniferous Rocks of East Lothian (Garlton Hills)." *Trans. Roy. Soc. Edin.* vol. xxxvii. part 1. p. 115,

CARBONIFEROUS LIMESTONE SERIES.

Dunbar and Cockburnspath District.—In the Carboniferous Limestone series there are eight or nine limestones, to which local names are given as indicated in the following section, in which the highest beds are placed at the top. The details given are chiefly obtained from the coast between Barness and Thorntonloch :— Mr. Clough.

Barness* east limestone	from 2 to 6 ft.
Strata, chiefly sandstone	50 ft.
Dryburn Foot impure limestone or calcareous sandstone, not always present	from 1 to 2 ft.
Sandstone and shale	10 ft.
Chapel Point limestone	9 or 10 ft.
Shale and thin coal smut	3 ft.
Fireclay and sandstone	20 ft.
Shale and thin flaggy sandstone	from 70 to 80 ft.
Skateraw upper limestone	from 1 to 2 ft.
Black Shale	from 3 to 5 ft.
Skateraw middle limestone	from 16 to 18 ft.
Coal	from 4 to 6 ins.
Fireclay	1 ft. 6 ins.
Shale and fireclay	6 ft. 6 ins.
Skateraw lower limestone	from 2 to 4 ft.
Shale and sandstone	23 ft.
Long Craig upper limestone	18 ft.
Shale, partly sandy	from 2 to 5 ft.
Thin coal in places.	
Long Craig middle limestone	3 ft.
Shale and sandstone	25 ft.
Long Craig lower limestone, mixed with bands of calcareous shale	27 ft.

The Long Craig lower limestone is seen better in the railway cutting near Broxmouth, where it is vertical, than on the shore. The Long Craig upper limestone and the Skateraw middle limestone are of much the same thickness, but they can generally be readily distinguished, the latter limestone being of a dark grey colour and evenly bedded, while the former is of a creamy colour with knobby bedding surfaces. Throughout this district, also, there is always, a little below the top of the Skateraw middle limestone, a band, 1 or 2 feet thick, crowded with *Saccammina Carteri*, while in the Long Craig upper limestone there is a band, 4 or 5 feet from the top, half made up of some cup coral, apparently a species of *Cyathophyllum*. The Skateraw lower limestone is dark and impure, and generally characterised by *Productus giganteus*. The interval between the Chapel Point limestone and the Skateraw upper limestone is considerably greater than that between any of the other limestones. In the Chapel Point limestone, near the middle, there are in some places thin lenticles of dark chert containing foraminfera large enough to be seen by the naked eye.

About 60 or 70 feet of beds, chiefly sandstone, are seen above the Barness east limestone at Barness, and also above the crinoidal sandstone which seems to represent this limestone on

* This is the name given in the six-inch maps to the point east of Catcraig.

Mr. Clough. the shore west of Broxmouth. In both these localities strata are probably very near the base of the Edge coals Midlothian, and, as the dip of the beds is seaward at angles v ing between 5° and 15°, it is probable that a succession of c bearing beds outcrop under the sea at a comparatively sl distance from the shore. The beds in the locality near B mouth are near some large faults and considerably distur but between Barness and the base of the Carboniferous Li stone series near Thorntonloch there is not much disturba and it would probably be worth while to prove whether th are not under-sea coals which could be advantageously worl In the Admiralty Chart (234 New Series) the 20-fathom passes rather more than a mile and a half E.N.E. of l.w.m Barness.

Dr. Crampton. *Aberlady and Keith District.*—The beds in Aberlady Bay shown in the following section, in descending order:—

Compact tough limestone with *Productus*; supposed to be the Skateraw lower limestone	from 3 to 4 ft.
False-bedded white sandstone	4 ft.
Sandy black shale	8 ft.
Calcareous shale	3 ft. 6 ins.
Dark blue compact limestone, 8 feet, full of polyzoa, etc., overlying a nodular encrinite limestone from 8 to 10 feet, with a few specimens of *Productus giganteus*. The two bands together are supposed to represent the Long Craig upper limestone	
Coal	10 ins.
Grey shale and fireclay	6 or 7 ft.
Coral limestone full of *Lithostrotion junceum* and *Lithostrotion irregulare*, and many other fossils; (probably the Long Craig middle limestone)	8 ft.

It is difficult to separate and draw definite boundaries for limestones inland, owing to the thick superficial deposits wh cover the ground almost everywhere, but the different bands recognisable in some of the quarries.

Mr. Bailey. *Haddington and Gifford District.* South-east of the m outcrop, the lowest limestone of the Carboniferous Limest series appear to form two outliers, one near Lennoxlove another near Kidlaw. A quarry in the Lennoxlove limest shows about 18 feet of argillaceous limestone, with *Produc longispinus*, crinoids and other fossils.

The limestone at Kidlaw has been extensively quarried, the whole mass is so much broken and disturbed that it see quite possible that it has been transported by ice. The cha teristic *Saccammina Carteri* band of the Skateraw middle li stone has been recognised in numerous fragments. At Skate this band occurs more than 100 feet above the base of the C boniferous Limestone series, and its presence at Kidlaw furnis an additional reason for doubting whether that exposure i normal outlier.

PLEISTOCENE.

Glacial and Post-Glacial Deposits.

Dunbar and Cockburnspath District.—A considerable proportion of the Drift is of a light gravelly character. In various coast sections beds of sand and gravel are exposed between reddish Boulder Clay, and near Oldhamstocks there is a great mass, perhaps 80 feet thick in places, of sand and gravel resting on Boulder Clay; a considerable part of the gravel seems derived from beds of conglomerate like those in the high-lying Old Red Sandstone area to the west. Mr. Clough.

In the drift-covered area there are various long banks and valleys which run from N.W. to S.E., and which are, perhaps, the result of erosion by marginal ice-streams. Many are cut by deep deans which fall in a N.E. direction.

Near Oldhamstocks there is a series of almost flat, wide-spread terraces of gravel. The highest is about 100 feet above the present burn, and its east limits are not well defined.

The 20-feet raised beach is seen in many places, and there are also various higher terraces near the coast, and reaching to heights of about 100 feet, but these last are only distinct near the mouths of burns, and it is not certain that they are due to marine erosion.

North Berwick District.—During the melting away of the ice sheet, streams were formed which have left their impress on many of the scars and rock faces between East Linton and Drem. Mr. Barrow.

The distribution of the marine sand at various altitudes round the coast, and its absence at similar altitudes in the interior, suggest that, a little inland, a small isolated cake of ice loaded with mud prevented the ingress of the sea and the formation of the 75-feet and 100-feet raised beaches.

Aberlady District.—The 25-feet and 100-feet raised beaches cover the solid rocks from Aberlady Bay inland as far as Spittal, near the railway line. In one place, on the Gosford Park Estate, blue clay, 25 feet thick, has been proved by a boring starting at a level of about 50 feet above the sea. Dr. Crampton.

Haddington and Gifford District.—Boulder Clay covers almost the whole district except where the streams have laid down tracts of alluvium, or where, along the Lammermuir flanks, the drift gravels are heaped up. It may be red and sandy, blue or faint bluish white, and encloses blocks of Carboniferous sandstone and coal, igneous rocks, and occasionally Highland metamorphic rocks. It also contains angular masses of soft sand, not unlike pseudomorphs after ice fragments. Silurian stones are absent, and big blocks of any kind are rare. Mr. Bailey.

Great terraces of sand and gravel are banked up against the Lammermuirs, and contain many sub-angular pieces of Silurian shale and greywacke. The terraces of gravel in the great recession which holds the tributaries of Gifford Water, reach up along the courses of the burns into Silurian territory, and they were in all probability deposited in water held up against the Lammermuirs by the retreating ice-sheet.

Mr. Bailey. No striæ have been observed in the country between Haddington and the Lammermuirs. There is, however, a series of features, running N. of E.N.E., which seem to be the result of ice moulding. The valleys among them now often hold small burns, and not infrequently are spread over with sand and gravel. Though the features are cut in solid rock they are swathed almost completely in Boulder Clay. This might be explained, perhaps, by supposing that the modelling was the result of marginal-ice streams during an advance or oscillatory retreat of the ice. So also might the fact that of the two hollows bounding Monkrig, the one further up the main valley is the deeper. The valley features above described, in some cases at any rate, terminate in the Tyne valley, two miles below Haddington. It is obvious that if these features are due to ice moulding, yet in the retreat of the glaciers they must often have furnished channels for the escaping waters.

ECONOMIC FEATURES.

Mr. Clough. Most of the area is highly cultivated, and perhaps as fertile as any part of Scotland. The richness of the soil about North Berwick and Dunbar is generally attributed to the great amount of igneous and ashy material which it contains.

Dunbar and Cockburnspath District.—Various statements concerning the possibility of finding workable coal have been already made in connection with the solid geology.

The only limestone now being quarried for burning is the Skateraw middle limestone; the quarry is near Oxwellmains, and at present about half the stone quarried is being sent to smelting furnaces in the West of Scotland. The Chapel Point limestone is sometimes quarried on the shore at Chapel Point, but only on a small scale and for road metal.

The Billsdean sandstone, which comes above the Cove oil shale, is exposed for a considerable distance along the shore and in Dunglass dean, and was once largely quarried. It furnished the stone of which Dunglass mansion house was built, and makes an excellent building stone, in most parts of a white or pale yellow colour, and is very easy to work and yet durable. The red sandstones near Branxton and Thornton were also at one time extensively wrought.

Cockburnspath and Oldhamstocks, and many farms, are supplied with water pipe from springs a short distance off. Many of these springs certainly issue from glacial sands and gravels lying over Boulder Clay, but no systematic investigation of them has been made.

Mr. Barrow. *North Berwick District.* The richness of the soil about North Berwick has led to the cultivation of almost the whole country, and there are few permanent pastures except the home parks around the large houses. The glacial sands form a poor soil much of which is planted, and here and there stiff Boulder Clay occurs which is not very profitable to work.

Mr. Barrow.

Of the igneous rocks, only the trachytic, such as the rock of North Berwick Law, have been used to any considerable extent as building material. The few beds of sandstone that are bare of drift are for the most part too soft for the construction of house walls. Almost any of them, however, make good field fences.

The black basaltic intrusive rocks make excellent road metal and have been largely quarried. A big quarry has been opened in the light grey non-porphyritic variety of trachyte, which is well suited for the purpose if taken some depth below the surface and broken small by machinery. The volcanic sheets are said not to form good road metal, as they split into flakes parallel to the bedding, and these when rolled tend to arrange themselves parallel to each other and do not bind together. But this difficulty could, perhaps, be overcome if the rocks were broken smaller by machinery; at present much of it is broken by hand.

The rocks do not seem to give an abundant water supply, and the water for North Berwick is piped from the Silurian uplands to the south. This is, perhaps, partly due to the smallness of the area, free from drift, into which water can sink, and to the absence of high ground to give a head to any water that may accumulate in the rocks. Where possible, the large farms are supplied by the North Berwick Water Company, in preference to having wells of their own.

Dr. Crampton

Aberlady District.—The only quarry of limestone that is at present being worked is that at Harelaw, Longniddry.

Mr. Bailey.

Haddington and Gifford District.—Coal used to be wrought in Sandersdean, but the workings are now discontinued. At Kidlaw, on the flank of the Lammermuirs, the limestone quarries have been abandoned, but there is a large quarry of basalt which provides excellent road metal and is very widely used in the neighbourhood.

For water supply Haddington relies upon two sources, one the sandstone cropping out on the side of Whitelaw Hill, and the other the great drift gravels which fringe the Silurian area and which have been tapped at Long Yester.

II. Palæontological Work.

Dr. Peach.

The Palæontological department in Scotland was carried on by Dr. Peach, with the assistance of Mr. A. Macconochie and Mr. D. Tait. As in former years, valuable assistance has been cordially given by Dr. Traquair, Dr. Wheelton Hind, and Mr. R. Kidston. The total number of fossils collected during the year and entered in the Survey List Books is 2,491.

Fossils to the number of 1,129 have been named and entered up in the list books during the season. Of these, only eighty-five from the Campbeltown Coal Field and the Lower Carboniferous rocks of Berwickshire were named by Dr. Peach. All the others have been determined by the following specialists to whom the thanks of the Geological Survey are due.

Dr. Peach. Dr. Traquair has named 270 fishes from the Ludlow and Downtonian rocks, several of which have been figured by him. He has further supplied the following report upon the new points of morphological interest which they exhibit:—

Dr. Traquair. "Among the fish remains collected by Mr. Tait during the past summer in the Upper Silurian rocks of the Lesmahagow district and submitted to me for determination and comment, are two which exhibit new points, which are eminently worthy of notice.

"*Lanarkia*, sp. undet. A fragment showing the front of the head and part of the body, referable to this genus on account of the dermal armature which consists of minute spines, along each lateral margin, are indications of a row of pouch-like structures exactly in the position of the supposed branchial pouches of *Cyathaspis*. The close affinity between the Cœlolepidæ and Pteraspidæ receives here a striking confirmation.

"*Lasanius problematicus*, Traq. A fragment of a large specimen from Birkenhead burn, showing the nuchal long rods, and a portion of the integument behind them. On wetting the specimen, the integument at once shows an obliquely striated appearance, apparently due to the presence of very delicate narrow band-like calcifications or hardenings, which run parallel with the nuchal rods, and consequently in a direction similar to that of the narrow body scales of *Birkenia*. This is fresh evidence in favour of the affinity of those two remarkable genera."

Dr. Traquair has also named thirty-three specimens of fishes from the Carboniferous rocks of Midlothian.

Dr. Peach. At Mr. Kynaston's request, Dr. Peach and Mr. Tait accompanied Mr. Kynaston to Glencoe and made a collection of fossils from some dark shales that lie near the base of the great volcanic plateau on the flanks of the Buachille Etive Mor. Mr. Tait there found specimens of the Lower Old Red Sandstone plants *Psilophyton* and *Pachytheca*—the *Œtheotesta devonica* Dawson—which determine the horizon of this volcanic plateau to be the same as that of Lorne and of the Ochil Hills. The specimens of *Pachytheca* are well preserved and show structure; the best of these have been placed in the hands of Mr. Kidston for future microscopic investigation. Regarding some of the specimens of *Psilophyton*, Mr. Kidston reports that the specimens were very fragmentary and could not be specifically identified, but they possess all the characters of small branchlets of *Psilophyton*. Mr. Kidston has further named 692 specimens of plant remains from the Carboniferous rocks of Berwick, Haddington and Dumfries.

A small collection of plants remains, made by Mr. Macconochie from the Campbeltown Coal Field, and a further collection made by Mr. McPherson, C.E., and forwarded by Mr. Lindsay Galloway to the Geological Survey, were submitted to Mr. Kidston who supplied the following notes and lists which corroborate the view hitherto held that the Campbeltown Coal Field is on the horizon of the "Edge Coals" of the Midlothian Basin.

Mr. Kidston. In all, three collections were submitted to Mr. Kidston for examination, which are referred to in the following report:—

"The first specimens were sent me by Mr. T. Lindsay Galloway, from the shale of the Main Coal, but were badly preserved and threw no light on the age of the rocks from which they were derived.

"The second lot was collected by Mr. A. Macconochie, some of which were from the same band, but in addition, he discovered a thin band of shale interleaved in sandstone cropping out in Machrihanish water, 320 yards west of pit, which contained some well preserved specimens, and the third collection was made later from the same band by Mr. McPherson, C.E., which was forwarded to the Geological Survey by Mr. Galloway. Mr. Kidson.

Only one specimen could be specially identified in Mr. Galloway's first collection :—

Stigmaria ficoides. Sternb. sp.
Loc. Wimbledon Pit, Machrihanish, near Campbeltown.
Hor. Roof of Kilkivin Seam.

The following were collected by Mr. Macconochie.

I. From Wimbledon Pit, Machrihanish.
Hor. Shale resting on Main Coal.

Sphenopteris elegans, Brongn. (rare).
1822. *Filicites* (*Sphenopteris*) *elegans*, Brongn. Class. d. végét. foss. p. 33. Pl. ii., figs. 2^a, 2^b.
1830. *Sphenopteris elegans*, Brongn. Hist. d. veget. foss. p. 172. Pl. LIII., figs. 1-2.
1877. *Diplothmema elegans*, Stur, Culm Flora, Heft ii., p. 130 (236). Pl. xiii., fig. 5, Pl. xiv., figs. 1-6.
1853. *Sphenopteris johnstoniana*, Tate in Johnston's Nat. Hist. of Eastern Borders, vol. i., p. 306, figs. 1-2.

Sphenopteris Linki, Göpp. sp. (very plentiful).
1836. *Gleichenites Linki*, Göpp. Syst. fil. foss. p. 182. Pl. i., fig. 1.
1845. *Sphenopteris Linki*, Unger. Synop. plant. foss. p. 67.
1877. *Calymmotheca Linki*, Stur. Culm Flora, Heft ii., p. 161 (267) Pl. xiii., figs. 1, 1^a, 2, 3, 4, 5^a, 5^b, 6.
1836. *Cheilanthites microlobus*, Göpp. Syst. fil. foss. p. 238. Pl. xiii., figs. 1-3.

Lepidodendron veltheimianum, Sternb.

Lycopod macrospores.

II. *Loc.* Bed of burn, Tirfergus Glen, at Limestone Section.
Hor. In sandy shale underlying the lower coal at Limestone Section.
Sphenopteris Linki, Göpp. sp.
Sphenopteris elegans, Brongn.

III. *Loc.* Machrihanish Water, 320 yards west from Wimbledon Pit.
Hor. Shale interleaved in Sandstone.
Sphenopteris Linki, Göpp. sp. Very plentiful.
Sphenopteris elegans, Brongn. Rare.
Sphenopteris, sp.
Diplotheca stellata, Kidston, n.g. et sp.

This last is a fern fructification allied to *Calymmatotheca*, Stur, but differs in the long linear *sporangia*, being united at the base in pairs. Six pairs of germinate *sporangia* spread starlike from a common point of attachment, giving the fossil much the appearance of a whorl of *Annularia* leaves.

The third collection was that made by Mr. McPherson, C.E.
Loc. Machrihanish Water, 320 yards west of Wimbledon Pit.
Hor. Shale interleaved in Sandstone.
Sphenopteris Linki, Göpp. sp. Very plentiful.
Cardiopteris polymorpha, Göpp. sp. *var. rotundifolia*, Göpp.
Of this last there was only a single pinnule.

The total number of species collected is small, but is sufficient to prove the Lower Carboniferous Age of the Coal Field, and I believe assign to it the definite position of the 'Edge Coal Series.'"

Dr. Peach. Early in the season the sections of the Carboniferous rocks exposed on the Berwickshire, Haddington, and Fife coasts were traversed for the purpose of familiarising the members of the Geological Survey with the order of succession of those beds, prior to the revision of the coal fields in the autumn. During one of these traverses Mr. Tait discovered on the Abden shore a bed of ash full of plant remains on the horizon of the Abden Limestones near the top of the Calciferous Sandstone series One of the specimens proved to be the remains of a fern new to Britain. Later in the season Mr. Kidston and Mr. Macconochie made collections from various localities in Fife, including the bed near Abden. These are referred to by Mr. Kidston in the following report:—

Mr. Kidston. "During the summer of 1902 the Calciferous Sandstone series of Fife was, at several localities, examined for fossil plants, which resulted in the discovery of some interesting species, a few of which had not previously been met with in Britain. On several of these excursions I had the assistance of Mr. Macconochie.

"Appended is a list of the localities which yielded fossil plants and the species which were collected from them:—

I. Shore about three-quarter mile N.N.E. of Kinghorn, almost immediately below the Combination Poor House.

The specimens were preserved in a fine Tuff.

Horizon. Near the top of the Calciferous Sandstone series, a short distance below the Hurlet Limestone.

The beds containing the fossils are formed of fine volcanic ash, and one of the beds from which some of the specimens were collected appears to have been only a small lenticular patch. The plants often lie obliquely to the bedding—their lower portion having been held in the mud while the upper part was floating in the water; the specimens thus frequently pass through more than one thin bed, which makes it impossible to secure complete examples.

The fossils at this locality were collected from two, if not three distinct beds, which were, however, separated from each other by only a short distance, probably not more than 2 or 3 feet, but owing to the distortion and bending of the strata, it was difficult to trace the beds, and, in fact, as already mentioned, some of them almost appeared as if they had been deposited in hollows of small extent.

The lower bed may be distinguished as Bed 1, and the uppermost as Bed 2.

This locality was first discovered by Mr. D. Tait.

Specimens from Bed 1:—

Rhacopteris paniculifera, Stur.

1875. *Rhacopteris paniculifera*, Stur, Culm Flora, Heft i. p. 72, Pl. viii., fig. 3.

This species is somewhat closely related to *Rhacopteris inæquilatera*, Göpp. sp. (*Adiantites lindseæformis*, Bunbury). It was not uncommon in this bed, and is a species I have not previously met with in Britain.

The late Mr. Charles Peach mentions having found *Rhacopteris paniculifera* at "Slateford, West Calder, etc.,"* but I am afraid there must be some mistake in these records, as I have never seen the plant either in the collection of the late Mr. Charles Peach or in any other collection which I have examined.

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* *Trans. Bot. Soc. Edin.*, vol. xiii., p. 47.

Rhacopteris transitionis, Ett. sp. Mr. Kidsto

1865. *Asplenites transitionis*, Ett. Foss. Flora. d. Mährisch-Schlesischen Dachschiefers, p. 23, fig. 8 (Denksch. d. Math. Naturwiss. Classe d. Kaiserl. Akad. d. Wissensch. vol. xxv.).

1875. *Rhacopteris transitionis*, Stur. Culm Flora. Heft i., p. 77, pl. viii. figs. 5 7 ; Heft ii., p. 319, pl. xv., fig. 14, 1877.

Several specimens were collected, but owing to their lying obliquely to the bedding, good specimens were difficult to procure.

Alcicornopteris sp.

A single example of a small species was met with. It is more delicate in all its parts than either *Alcicornopteris Zeilleri* Vaffier,* or the *Alcicornopteris convoluta*, Kidston,† and is, I believe, a new species.

Specimens from Bed 2.

Sphenopteris n. sp.

Sphenopteris sp. indeterm.

A few specimens were got from a third bed, which, as far as could be determined from the twisted and irregularly bedded strata, seemed to occupy a position between Beds No. 1 and No. 2.

Rhodea moravica, Ett. sp.

1865. *Trichomanes moravicum*, Ett. Foss. Flora d. Mährisch-Schlesischen Dachschiefers, p. 24, fig. 9, pl. vi., fig. 4.

1875. *Rhodea moravica*, Stur, Culm Flora, Heft i., p. 38, pl. x., figs. 3–7 ; pl. xi., fig. 1.

1877. *Calymmotheca moravica*, Stur. Culm Flora, Heft ii., p. 278. Rare in the bed.

Rhacopteris inæquilatera, Göpp. sp.

1860. *Cyclopteris inæquilatera*, Göpp. Foss. Flora d. Silur., Devon. u. unter. Kohlenf., p. 72, pl. xxxvii., figs. 6–7.

1861. *Adiantites Lindseæformis*, Bunbury. *Geol. Survey of Great Britain:* The Geology of the Neighbourhood of Edinburgh, pp. 144. 151, fig. 26.

Also rare in this bed.

Rhacopteris sp.

Sphenopteris crassa, L. & H.

1835. *Sphenopteris crassa*, L. & H. Fossil Flora, pl. clx.

1883. *Sphenopteris crassa*, Kidston, *Proc. Roy. Phys. Soc. Edin.*, vol. vii., p. 235, pl. v., figs. 1–2.

1875. *Sphenopteris Ksowitzensis*, Stur, Culm Flora, Heft i., p. 32, pl. vi., fig. 8.

Several specimens were collected, but all in a fragmentary condition owing to the specimens lying somewhat obliquely to the bedding.

II. Shore, Breakboats, Pittenweem. Bed No. 367 of Mr. Kirkby's List.

Horizon. In sandy shales, a little above Encrinite bed and 2,152 feet below Hurlet Limestone.

Sphenopteris pachyrrhachis Göpp. var. *stenophylla, Göpp.*

1852. *Sphenopteris pachyrrhachis* var. *stenophylla, Göpp.* Foss. Flora d. Uebergangs., p. 143, pl. xiii., figs. 4–5.

Calymmatotheca affinis, L. & H. sp.

1832. *Sphenopteris affinis*, L. & H. Fossil Flora, vol. i., pl. xlv.

1887. *Calymmatotheca affinis*, Kidston, Trans. Roy. Soc. Edin. vol. xxxiii. p. 137, pl. ix., figs. 18–22.

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* Étude géologique et paléontologique du Carbonifère Inférieur du Maconnais, p. 125, pl. vi. fig. 5 ; pl. viii., figs. 1, 1*a*, 1*b*, 1c, 1*d*, 1e, 1*f* (Annal. d. l'Université de Lyon. Nouv. sér. i., Sciences, Médicine, fasc. 7, 1901).

† *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 152, pl. viii., figs. 11–15, 1887.

Mr. Kidston.

Asterocalamites scrobiculatus, Schl, sp.

1820. *Calamites scrobiculatus*, Schlotheim. Petrefactenkunde, pl. xx., fig. 4.

1828. *Calamites radiatus*, Brongn. Hist. d. Végét Foss., p. 122, pl figs. 1–2.

1852. *Calamites transitionis*, Göpp. Foss. Flora d. Uebergangs pl. iii. figs. 1–6 (? fig. 7).

1862. *Calamites* (*Asterocalamites*) *radiatus*, Schimper, Terr. d. d. Vosges, p. 321, pl. i.

1875. *Archæocalamites radiatus*, Stur, Culm Flora., Heft i., p. figs. 3–8; pl. ii., pl. iii., pl. iv., pl. v., figs. 1–2; Heft ii., y. 1 pl. ii. (xix.), figs. 1–6; pl. iii. (xx), figs. 1–2; pl. iv. (xxi.), 1*b*; pl. v. (xxii.), fig. 1.

Lepidophloios Scoticus, Kidston.

1885. *Lepidophloios Scoticus*, Kidston, Ann. & Mag. Nat. His 5, vol. xvi., p. 137, pl. vii., fig. 14.

1893. *Lepidophloios Scoticus*, Kidston, Trans. Roy. Soc. Edi xxxvii., p. 561, fig. p. 551; pl. i. figs. 2, 3; pl. ii. figs. 5–7.

III. Right bank of Cameron Burn, quarter of a mile east of Str Mill, near St. Andrews.

Horizon. In Limestone Bed about the horizon of the Burdi Limestone.

Bothrodendron Depereti, Vaffier.

1901. *Bothrodendron Depereti*, Étude géol. et paléont. du Carb Inférieur du Maconnais, p. 139, pl. xi., figs. 3, 3*a*, 3*b*; pl. 4, 4*a*.

This species, which has not previously been met with in Britain, is related to *Bothrodendron wükianum*, Kidston,* but is distinguished larger size and the ornamentation of the outer surface of the cort *Bothrodendron Depereti*, Vaffier, the striation of the outer surface bark is not flexuous, as in *Bothrodendron wükianum*, but runs strai to the leaf scars both below and above them, whereas in *Bothrod wükianum* the striations are more or less flexuous, and are deflecte above and below the leaf scars, bending round them, and thus leavi scars surrounded by an elongated rhomboidal smooth space.

Only a single specimen was found—

Lepidodendron Veltheimianum, Sternberg.

1826. *Lepidodendron veltheimi*, Sternb. Essai flore monde pri i. fasc, 4, p. 48, pl. lii., fig. 3.

1826. *Lepidodendron veltheimianum*, Sternb. (ibid. I.), i. fasc. 4

1885. *Lepidodendron veltheimianum*, Kidston (in part), Ann. an Nat. Hist. Ser. 5, vol. xvi., p. 243, pl. iii., pl. iv., fig. 2 (not fig pl. vi., figs. 11, 11*a*, 11*b*.

1902. *Lepidodendron Veltheimianum*, Kidston, Proc. York. Ge Polytech. Soc., vol. xiv., part iii., pp. 347, 381, 383, pl. lvi., pl. lvii., fig. 1.

Not uncommon, especially the smaller branches.

Cordiates, sp.

A single fragment of a leaf was collected.

IV. Right bank, Wakefield Burn, quarter of a mile north-east of l sawmill, Dunino, near St. Andrews.

Horizon. Arenaceous shale in massive sandstones.

Calymmatotheca affinis, L. & H. sp.

Not common in the Bed.

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* Kidston, *Ann. and Mag. Nat. Hist.*, Ser. 6, vol. iv. p. 60, pl. i 3–4 (not fig. 2), 1889: also *Proc. Roy. Phys. Soc. Edin.*, vol. x., p. 94, figs. 3–4 (not fig. 2), 1889.

Cardiopteris frondosa, Göpp. sp. Mr. Kidston.

1852. *Cyclopteris frondosa*, Göpp. Foss. Flora d. Uebergangs. p. 163, pl. xiv. figs. 1-2.

1862. *Cyclopteris Kœchlini*, Schimper, Terr. d. Trans. d. Vosges, p. 340, Pl. xxviii.

1865. *Cyclopteris Haidingeri*, Ett. Foss. Flora d. Mährisch-Schlesischen Dachschiefers, p. 20, fig. 5, Pl. v.

1869. *Cardiopteris frondosa*, Schimper, Traité d. paleónt végét, vol. i., p. 453, Pl. xxxv.

The isolated pinnules of this species were very plentiful in a bed of a grey arenaceous shale. In no case did we find the pinnules united to the rachis.

Many years ago, the late Mr. Gibbs, fossil collector to the Geological Survey, met with well preserved isolated pinnules of this species "in bed of burn, Stravithie, four miles south of St. Andrews. We tried to rediscover this bed, but failed to do so. The matrix of those discovered by Mr. Gibbs is a hard reddish sandstone, and his locality could not have been far distant from the bed containing *Cardiopteris frondosa* found by us.

While the revision of the Carboniferous areas was being carried on by Mr. Clough in the region south of Dunbar during the autumn, Mr. Macconochie made collections of plant remains from several horizons. He not only searched the bands recorded by the late Mr. Richard Gibbs and the late Mr. James Bennie, but he discovered several other plant-bearing beds which yielded him a large collection. These have been submitted to Mr. Kidston who supplied the following lists, many of the plants being entirely new to the locality and some of them very rare. Dr. Peach.

List of Fossil Plants collected by Mr. A. Macconochie from the Calciferous Sandstone series in the neighbourhood of Cockburnspath, Berwickshire, by Mr. Kidston—

Although none of the plants in this collection are new to Britain except one which I am unable at present to determine, the three following are very rare. Mr. Kidston

Sphenopteris subgeniculata, Stur sp.
Rhodea machaneki, Ett. sp.
Rhodea patentissima, Ett. sp.

A Locality. A quarter of a mile and fifty yards E.S.E. of entrance to Cove Harbour, Cockburnspath.

Horizon. Cement-stones of Ballagan series.

Stigmaria ficoides var. *undulata* Göppert.

1841. *Stigmaria ficoides* var. *undulata*, Göpp. Gatt. d. foss. Pflanzen lief. 1-2, p. 19, Pl. ix. figs. 5 (? 6), 7, 8, (? 9).

1852. *Stigmaria ficoides* var. *undulata* Göpp. Foss. Flora d. Uebergangs. p. 245, Pl. xxxii. fig. 2.

B Locality. A quarter of a mile south-east of Linkhead, near Cockburnspath.

Horizon. Grey shale in sandstone, overlying the Linkhead Limestone.

Sphenopteris subgeniculata, Stur sp.

1877. *Diplothmema subgeniculatum* Stur, Culm Flora. Heft ii., p. 135, Pl. xii., figs. 8, 9, 10.

1889. *Sphenopteris subgeniculata*, Kidston, Trans. Roy. Soc. Edin., vol. xxxv., p. 424, Pl. ii., fig. 10.

Rhodea machaneki Ett. sp.

1865. *Trichomanites machaneki* Ett. Foss Flora d. Mährisch-Schlesischen Dachschiefers, p. 25, fig. 12.

1875. *Rhodea machaneki* Stur, Culm Flora Heft i. p. 34.

Rhodea patentissima, Ett. sp.

Mr. Kidston. 1865. *Hymenophyllites patentissimus*, Ett. Foss. Flore d. Mährisch—Schlesischen Dachschiefers, p. 26, fig. 13, pl. vii., fig. 4.

1875. *Rhodea patentissima*, Stur. Culm Flora, Heft i., p. 36, pl. ix., fig. 1-9.

Rhodea moravica, Ett. sp.

1865. *Trichomanes moravicum*, Ett. Foss. Flore d. Mährisch—Schlesischen Dachschiefers, p. 24, fig. 9, pl. vi., fig. 4.

1875. *Rhodea moravica*, Stur. Culm Flora, Heft i., p. 38, pl. x., figs. 3-7; pl. xi., fig. 1.

1877. *Calymmotheca moravica*, Stur. Culm Flora, Heft ii., p. 278.

Sphenophyllum tenerrimum, Ett.

1874. *Sphenophyllum tenerrimum*, Ett. mscr. Helmhacker. Beitr. z. Kenntniss d. Flora d. Südrandes d. oberschlesisch-polnischen Steinkohlenform. p. 28, pl. iii., figs. 5-16 (in Berg. u. Hiittenmann. Jahrb., vol. xxxii.).

1877. *Sphenophyllum tenerrimum*, Ett. mscr, Stur. Culm Flora, Heft ii., p. 214, fig. 23 (p. 220), pl. vii. (xx.) figs. 1-14.

C Locality. Shore at Standalane, about half a mile S.E. of Linkhead.

Horizon. In Clayey Shale beds above Linkhead Limestone and a little above Beds at locality *B*.

Calymmatotheca affinis, L. & H.

1832. *Sphenopteris affinis*, L. & H. Fossil Flora, vol. i., pl. xlv.

1877. *Calymmatotheca affinis*, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 137, pl. ix., figs. 18–22.

Very plentiful and specimens well preserved.

D Locality. Bay near Standalane, about half a mile S.E. of Linkhead.

Horizon. Bituminous shale resting on thin coal.

Sphenophyllum tenerrimum, Ett.

E Locality. Ninety yards south of entrance to Cove Harbour, Cockburnspath.

Horizon. In shale and in Ironstone band in the shale, on horizon of Scremerston Series.

Rhodea moravica, Ett. sp.

Cardiopteris polymorpha, Göpp, sp.

1860. *Cyclopteris polymorpha*, Göpp, Foss. Flora d. Silur, Devon, u. unter. Kohlenform. p. 78, pl. xxxviii., figs. 5[a] and 5[b].

1865. *Cyclopteris hochstetteri*, Ett. Foss. Flora d. Mährisch-Schlesischen Dachschiefers, p. 21, pl. vi., fig. 3.

1869. *Cardiopteris polymorpha*, Schimper, Traité d. Paléont. végét. vol. i., p. 452.

1875. *Cardiopteris hochstetteri*, Stur, Culm Flora, Heft i., p. 48, pl. xiv., fig. 2 (? fig. 3).

F Locality. Shore a little below high water mark, ninety yards south of entrance to Cove Harbour, Cockburnspath.

Horizon. About thirty feet below the lowest of the Cove Limestones.

Sphenopteris dissecta, Brongn.

1829. *Sphenopteris dissecta*, Brongn. Hist. d. végét. foss. p. 183, pl. xlix., figs. 2-3.

1877. *Diplothmema Schützei*, Stur, Culm Flora. Heft ii., p. 128 (234), pl. xiii. (xxx) figs. 4[a],—4[g].

Cardiopteris polymorpha var. *rotundifolia*, Göpp.

1860. *Cyclopteris polymorpha* var. *rotundifolia*, Göpp. Foss. Flora d. Silur. Devon. u. unter Kohlenform. p. 78, pl. xxxviii., figs. 6[a] and 6[b].,

Asterocalamites scrobiculatus, Schl. sp.

1820. *Calamites scrobiculatus*, Schlotheim, Petrefactenkunde, p. 402, pl. xx., fig. 4.

1828. *Calamites radiatus*, Brongn. Hist. d. végét. foss. p. 122, pl. xxvi., figs. 1 2. Mr. Kidst

1852. *Calamites transitionis*, Göpp. Foss. Flora d. Uebergangs. p. 116, pl. iii., figs. 1 6 (? fig. 7).

1862. *Calamites* (*Asterocalamites*) *radiatus*, Schimper, Terr. d. Trans. d. Vosges, p. 321, pl. i.

1875. *Archæocalamites radiatus*, Stur, Culm Flora, Heft i., p. 2, pl. i., figs. 3-8; pl. ii.; pl. iii.; pl. iv.; pl. v., figs. 1-2, Heft ii., p. 18 (74), pl. ii. (xix), figs. 1-6; pl. iii. (xx) figs. 1-2; pl. iv. (xxi), figs. 1, 1b; pl. v. (xxii), fig. 1.

Lepidophyllum lanceolatum, L. & H.

1831. *Lepidophyllum lanceolatum*, L. & H. Foss. Flora, Vol. i., pl. vii., figs. 3-4.

G Locality. Outcrop in slope above Cove Harbour, Cockburnspath.

Horizon. Sandstone and red Ironstone band. Same band as locality E.

Calymmatotheca affinis, L. & H. sp.

Cardiopteris polymorpha var. *rotundifolia*, Göpp.

The isolated pinnules of this fern fill a band of red Ironstone 2 to 3 inches thick.

Asterocalamites scrobiculatus Schl. sp.

Lepidodendron Rhodeanum, Sternb.

1820. "*Schuppenpflanze*," Rhode, Beitr. z. Pflanzenkunde der Vorwelt, p. 7, pl. i., figs. 1a, 2, 3, 4.

1826. *Lepidodendron rhodeanum*, Sternb. Essai flore monde prim. fasc. iv. p. xi.

1852. *Sagenaria depressa*, Göpp, Foss. Flora d. Uebergangs. p. 179, pl. xliii., figs. 5-6.

Lepidophyllum lanceolatum, L. & H.

Lepidostrobus sp.

H Locality. Bay north-west of Cove, Cockburnspath.

Horizon. Shale resting on oil shale band. About two feet above Lowest Cove Limestone.

Calymmatotheca affinis, L. & H. sp.

Dr. Wheelton Hind has named thirty-one specimens of Lamelli- Dr. Peach
branchs from the beds underlying the Campbeltown Coals. The lamellibranchs from the rocks of the Canonbie Coal Field were also submitted to him, and he has named eighteen specimens. The latter corroborate the evidence obtained from the plant remains by Mr. Kidston that the rocks in which they occur are of Coal Measure Age.

The collection of Lower and Upper Silurian trilobites belonging to the Geological Survey, and kept in the Museum of Science and Art, Edinburgh, numbering 346 specimens, has, during last year, been examined by Mr. F. R. Cowper Reed, of the Woodwardian Museum, Cambridge, in connection with his forthcoming monograph to be published by the Palæontographical Society. The value of the collection has thus been much enhanced, as he has revised the previous determinations and brought the nomenclature up-to-date. Mr. Cowper Reed has also examined the small collection of fragmentary trilobite remains from the Durness Limestone belonging to the Survey, and has generously supplied notes upon them.

III.—Museum Work.

Mr. Goodchild. Mr. Goodchild, Curator of the Geological Survey Collections in the Edinburgh Museum of Science and Arts, reports that the Fourth Edition of the *Guide to the Geological Survey Collections* was published early in the year.

In connection with the rock-specimens, a special case has been devoted to the exhibition of a selected series illustrative of the Eruptive Rocks of Tertiary age from Skye, which were arranged with the co-operation of Mr. Harker in accordance with the latest information upon the subject.

Mr. Macconochie has arranged the collections of Scottish Jurassic fossils, and has also indicated by a special mark the zonal forms of the graptolites. Selections of duplicate rock-specimens and fossils have been presented to the Royal College of Science, London; the Universities of Cambridge and Oxford; and to the Corporation of Glasgow for exhibition in the Kelvingrove Museum.

The draft Catalogue of the specimens exhibited in the under cases, referred to in a former Report, has now been completed.

Miss Jane Donald has presented specimens of Scottish graptolites and of Carboniferous fossils from Liddesdale and Arran to the Geological Survey Collection.

Photographic Work. During the past season Mr. Lunn visited the district round Pitlochry, the valley of the Garry and Strath Tay, included in Sheet 55, and took 103 photographs illustrating the geology of these areas.

III.--IRELAND.

FIELD WORK.

Belfast District.

Mr. G. W. Lamplugh, District Geologist.
Mr. J. R. Kilroe,
Mr. A. McHenry,
Mr. H. J. Seymour, B.A. } Geologists.
Mr. W. B. Wright, B.A.
Mr. H. B. Muff, B.A.

The mapping of the superficial deposits of the Belfast area was completed during the year and the results will be published on a special map in which Belfast is centrally placed. The area in question extends for eighteen miles in an east and west, and twelve miles in a north and south direction, and is divided into three well-marked physical regions, the boundaries of which cross the map in a general north-east and south-west direction. The north-west portion is occupied by the Basaltic Uplands, the central portion by the Triassic Lowlands or Lagan Valley, of which Belfast Lough may be regarded as an extension, and the south-eastern portion by the Silurian Uplands, whose continuity is interrupted by the Pre-Triassic depression which connects the central valley with Strangford Lough.

The most pronounced physical feature in the district is the bold and occasionally precipitous escarpment which marks the termination of the basaltic plateau, a region of high ground which slopes westward and attains its greatest elevation (Divis Mountain, 1567 feet) in a range of hills near the edge of the escarpment. The Upper Cretaceous and patches of Lower Jurassic rocks emerge only on the steep slopes of the escarpment, with a broader belt of Triassic marl below which causes the overlying rocks to break away in huge slips.

The central area of low ground is formed of the Triassic marls and sandstone, more or less deeply covered with drift. This Drift extends towards the east and south-east, and effectually conceals the junction between the Trias and Silurian, thus rendering the boundary between the central valley and the Silurian Uplands less marked than that between the former and the Basaltic Uplands.

FIG. 5.

INDEX TO BELFAST SHEET.

No part of the district is free from glacially transported materials, though these are very unequally distributed, being accumulated to a great depth in some places and in others merely sprinkled thinly in hollows among uneven surfaces of bare rock; and they also vary greatly in composition in different parts of the district. Mr. Lamplugh.

The most usual form of this glacial drift is a tough unstratified boulder-clay in which the included stones are chiefly of basalt, chalk and sandstone in the country west of the Lagan, and of the same with a preponderating addition of slate fragments in the

Mr. Kamplugh

country east of that river. Where unweathered this clay is often calcareous, but not in the same degree as the richly calcareous boulder clays of the Dublin district mentioned in last year's report. Besides these local materials, the boulder-clay usually contains a few stones of distant origin such as quartzite, gneiss, granite, etc., probably transported from North Antrim, and riebeckite-rock like that of Ailsa Craig. These boulders always indicate a transport in a southerly direction. Much information regarding these far-transported boulders has been placed on record by members of the Belfast Naturalists' Field Club, and will be drawn upon in compiling the memoir. Fragmentary marine shells have also been obtained from these clays at several localities, but are usually rare. The best collections were made many years ago when excavations for the waterworks reservoirs on the Antrim Road were in progress; these are fortunately preserved in the Museum of the Belfast Natural History and Philosophical Society, and have been carefully worked out and added to by Mr. S. A. Stewart. Foraminifera also occur in these drifts, and have been closely studied by Mr. J. Wright of Belfast. As noted below, shell fragments have been found during our survey at points farther inland than the previous records for the district.

Stratified drift material, in the form of gravel, sand and laminated clay, is less widely distributed than the boulder-clay and is confined in this district to the principal valleys, and to the lower ground among the hills, differing in this respect from the stratified drift of the Dublin area, which extended upward to the highest levels attained by the Glacial deposits, as described in last year's report.

Glacial striæ were observed at a few places on the basaltic upland, but were found most abundantly on the Silurian ground, where the rock-surfaces are better adapted for their reception and preservation. Some details regarding these markings will be given subsequently.

DRIFTS OF THE BASALTIC UPLAND.

Mr. Wright.

The deeper sections of boulder-clay in the valleys of the plateau nearly always exhibit two bands, an upper, composed almost entirely of basaltic material with an occasional flint or other foreign pebble, and a lower, which although largely basaltic, contains abundant chalk and has a highly calcareous matrix, the line of separation between these clays being usually fairly sharp. Either the one or the other of these divisions is, however, occasionally absent; and sometimes where both are present their junction is ill-defined. They sometimes include impersistent layers of stratified silt and sand. The only organisms hitherto recorded from these upland boulder clays are *Ostracoda*, *Foraminifera*, and fry of two *Mollusca*, found by Mr. J. Wright of Belfast in the washings of a boulder clay occurring at an altitude of 1300 feet on Divis Mountain, and at 800 feet on Wolf Hill. Shell fragments were, however, collected from the boulder clay farther westward

during the mapping of the ground, including a broken valve of *Astarte sulcata* from a section in the bank of the Clady Water near Gibsonstown, and a fragment of the same species from a section of chalky boulder-clay in the Rushyhill River, about five miles farther southward. Mr. Wright

The same association of shell-fragments with the Ailsa Craig rock which was commented on last year in the Dublin district was again observed during the present year's work. Thus, pebbles of this rock were abundant in many places on the plateau, and were found up to an altitude of 875 feet above O.D. in sections three-quarters of a mile east of Priest's Hill. Mr. Muff.

Fragments of the same rock were also noticed at the surface on the northern slope of White Mountain; and, like the flints, which are often abundant in the soil of the upland where the basalt now lies immediately beneath the surface, such travelled fragments probably indicate the former existence of a thin drift-covering which has been removed by denudation. Mr. Kilroe.

The boulder-clay of the plateau usually forms smooth gentle slopes and is rarely heaped up into the drumlins which are so prevalent in other parts of the district. Two well-marked drumlins were, however, observed on the upland north of White Mountain, with axes trending approximately E. 20°S.

Irregular mounds of gravelly drift, due to the action of water in assorting materials of similar character to those which form the boulder-clay, are strewn along several of the valleys which carry the drainage of the plateau westward to Lough Neagh. These mounds cluster more thickly and are also larger and steeper along the courses of the streams, often occurring in the angle between two confluent streams. Mr. Wright

These features are especially well-marked in the valley of the Clady Water. In this district there are also traces of the action of glacial flood-waters in the form of several steep-sided valleys cut across the subsidiary water-sheds through the basalt and its drift-covering.

One of these valleys, about 35 feet deep, crosses the water-shed between Carnaghliss and Ballyhill, serving now only to carry off the drainage of a small bog. A gravelly deposit in the Clady Water depression corresponds in level with this channel and has the characteristic flat top, steep sides, and well-marked current bedding of a delta. This delta may have been formed by the Clady Water and a tributary stream when entering a glacial lake whose overflow was through the above mentioned channel.

At a later period, a portion of the valley near Gibsontown appears to have been flooded owing to the presence of a barrier of drift athwart the depression, so that a small lake was formed which probably persisted into post-glacial times, until the stream which flowed from it had sunk its channel through the barrier. This episode is marked by a series of laminated clays resting on the boulder clay and covered by later flood-gravels.

Mr. Wright observed four examples of glaciated surfaces on the basalt, the direction of the striæ reading between E. 17 S.

Mr. Wright. and E. 37 S., with cross-striæ in one case, under the shelter of a small boss, reading E. 45 N.—W. 45 S. Mr. Kilroe also found striæ in two places on the basaltic upland which indicated a south-easterly movement of the glaciating agent.

The upper slopes of the escarpment are usually too steep to permit the drift to lodge, except here and there in narrow strips; but in the lower gaps where the escarpment recedes or is trenched by valleys, as in Collin Glen and at Glengormly, the boulder-clay clothes the slopes and extends over the summit. Some of the slips under the steeper portions of the escarpment appear to be preglacial, as the boulder-clay sweeps smoothly over them; others however are later than the deposition of the clay.

DRIFTS OF THE TRIASSIC LOWLANDS.

The slopes of Triassic marl at the foot of the escarpment of basalt and chalk are overspread with tough red boulder clay largely derived from the underlying marl, and north of Belfast no other drift is found between the escarpment and the shores of the Lough. But in the lower part of the depression, along the course of the river Lagan, great masses of stratified drift, in the form of gravels and and laminated 'warp'-clay, are encountered, and are sometimes predominant over the boulder clay. The investigations have not at present included enough of the valley to enable the southward limits of these deposits to be determined, and until this is done, some uncertainty will Mr. Kilroe. remain in regard to them; but there can be no doubt that they represent water-borne sediments, derived from the same source as the materials of the boulder-clay. These deposits enter the district on the south near Lisburn in an irregular band about three miles in width, fringing the Lagan on both sides, but contracting somewhat suddenly northward. They nearly always rest upon boulder-clay, and in the northward part of their course are also sometimes overlain by boulder-clay of a more marly character and containing less chalk than that below. To the westward of Lisburn, and between that place and Dunmurry, a series of conspicuous mounds and ridges of gravel showing the characteristic esker-structure may be observed. It was originally believed that these ridges formed a single esker-train which ran eastward to Lisburn and thence north-eastward to Dunmurry, but Mr. Kilroe is of opinion that two distinct eskers are represented, one of which, running south-west from Dunmurry, terminates in a delta-fan of sand near Lisburn, while the other, starting near Milltown, goes south-westward and terminates similarly at Redhill, beyond the western boundary of the present map. Another delta-like spread of sand which occurs three-quarters of a mile W. by S. of Lisburn, is believed to mark a later stage when the waters which formed the last-mentioned esker broke away from their channel at this point. Sections in these esker-gravels sometimes show well-marked faulting on a small scale.

Besides these esker-ridges and mounds with their characteristic [illegible]ed-bedding, the stratified drifts are spread out in more or

less horizontally-bedded sheets which in the southern part of the district consist largely of gravel, but become more sandy northward, until finally, north of Malone, they contain no gravel, and are composed entirely of fine loamy sand with thin seams of laminated red clay or warp. It is suggested that these deposits were laid down in a temporary lake which occupied the valley when Belfast Lough was blocked with ice. Further evidence for the existence of this lake is found in the presence of gravelly deposits along the slopes of the Silurian hills to the eastward of the valley, forming fringing banks and rude terraces, at a height of about 165 feet above O. D. These gravels are most conspicuous in the neighbourhood of stream-channels descending from the high ground. They appear to indicate the arrest of the burden of these streams, and its arrangement at the margin of the old lake. The highest part of the lowland sands is however about 20 feet higher than the level of these gravels. Mr. Kilroe.

The broad low ridge on the southern side of Belfast, which separates off a portion of the old Lagan valley into a subsidiary basin now drained (and sometimes flooded) by the Blackstaff stream, is principally composed of loamy stratified sands, in places not less than 50 feet thick, which are the direct prolongation of the stratified drifts above described. These sands are over-lapped on both flanks of the ridge by red marly boulder-clay which becomes broken into patches and thins out on the upper slopes of the ridge. At their base the sands pass into a few feet of finely laminated silty clay or 'warp' which is frequently rippled-marked, and they appear also to fade off laterally into similar material, thus forming a huge lenticle resting upon and partly covered by boulder clay. This lenticular arrangement seems to be in part due to original inequality of deposition and in part to the erosion of the stratified mass during the deposition of the upper boulder-clay. Mr. Lamplugh.

The sands expand again on the eastern side of the Lagan, and are well displayed in the south-eastern suburbs of Belfast between Newtownbreda and Ormeau Park; and it is probably the same series which reappears to the northward of the clayey low ground drained by the Conn's Water, and forms the much-dissected sandy terrace extending along the eastern side of Belfast Lough to Holywood. Along the inner margin of this terrace, where it is dominated by steep hill-sides of Silurian rock, the material again becomes gravelly; and on the southern outskirts of Holywood there is an irregular mass of gravel which probably represents the delta-deposit from a small 'dry gap' on the adjacent hill-slope. This 'dry gap' is a short ravine crossing the narrow spur of slate-rock which bounds Holywood Glen on the west; it may be explained as the 'overflow channel' of waters which were impounded in the Glen and escaped westward into the Belfast basin.

The only organisms that have been detected in the stratified drifts above described are foraminifera, found very sparsely in the sands of South Belfast by Mr. J. Wright.

DRIFTS OF THE DUNDONALD VALLEY.

Mr. Kinahan. The Pre-Triassic depression, now lined with Triassic sandstones, which runs from the head of Belfast Lough to the head of Strangford Lough, contains a complex drift series, in part stratified and in part unstratified. At the wide entrance to the valley, east of Belfast, the loamy sands already described are largely replaced by gravels, which at Neill's Hill are intercalated with bands of boulder-clay, as described by Miss S. M. Thompson (Madame Christen).* At this place both the gravel and the boulder clay have yielded shell-fragments.

Mr. Muff. The gravels are continued thence into the valley at Dundonald in moundy esker-like features, but farther eastward they contract into rude much-dissected terraces lining the boulder-clay slopes of an irregular inner valley. The arrangement of these deposits Mr. Seymour. implies that they were the product of an outflow of water from the westward into Strangford Lough. Around the head of the Lough, north and north-east of Comber there is a low-lying tract of about 2 square miles of sand, which appears to represent the delta-fan formed at the same period. Some oval tracts of boulder-clay rising above this sand-plain are evidently the tops of half-buried drumlins. Patches of sand and gravel also occur here and there along the eastern shore of the Lough as far as the operations of the Survey have been extended. At Castle Espie, overlying the small patch of Carboniferous Limestone, part of the drift is composed of loamy sand and stones, the material being unstratified and the stones scattered just as in a boulder-clay, although the matrix is mainly sand derived from the Triassic Sandstones.

Mr. Muff. On the opposite side of the Lough, around Newtown Ards, there is a discontinuous strip of gravel banked against the foot of the hills, which is composed principally of Silurian débris. It has probably been accumulated as the delta of flood-waters passing through the hollow in the hills between Bangor and Newtown Ards, as disconnected patches of moundy gravel occur along nearly the whole course of this hollow.

DRIFTS OF THE SILURIAN UPLANDS.

Mr. McHenry The drift of the hilly Silurian ground between the sea and the Dundonald valley consists almost entirely of boulder-clay, which, for the most part, is heaped up into steep-sided oval hills or "drumlins." These are set thickly over the district, and give it the curious hummocky appearance referred to in the homely simile sometimes applied to Co. Down—that it is the "basket-of-eggs county." Save for a few high ridges of bare slate, these drumlins form the most prominent features among the hills, and it is often only in the hollows between them that rock is revealed. The boulder-clay in these drumlins is frequently known to be 40 feet or more in thickness; and in ravines bordering the Dundonald valley it is seen to attain a thickness of

Proc. Belfast Naturalists' Field Club, 1893-94, pp. 122-123.

at least 80 feet. Although the drumlins are perhaps rarely actually moulded upon rock-bosses, their distribution seems to indicate that they are in some manner caused by the unevenness of the rocky floor, as it is mainly in districts where the rocks form an irregularly broken surface that these hillocks of boulder-clay occur. Their comparative rarity on the basaltic upland, and their feeble development on the limestone plain near Dublin commented on in last year's report, may be thus explained. As was pointed out by Rev. M. H. Close, the longer axes of these mounds usually coincide in direction with the trend of the glacial striæ. Mr. McHenry

Glaciated rock-surfaces are of common occurrence throughout the Silurian ground. In the district under consideration, their general trend is towards S.S.W. in the vicinity of the Lagan valley, and due S. on the high ground farther eastward, but with local deviations in the direction of Strangford Lough on the lower slopes.

The glacial phenomena of the Silurian hilly ground south of the Dundonald Valley are very similar to those of the district above described, except that in several places in the valleys there is a local development of gravelly stratified drift. Drumlins of boulder-clay are abundant, and the outcrops of slate-rock occur principally in hollows between them. These drumlins have frequently obstructed the pre-glacial drainage-channels, forcing the present streams into tortuous new courses, in part following the old hollows, and in part breaking away from them in steep-walled rocky gorges. Thus the Gransha River, which describes three sides of a rectangle, passes through three or four late-glacial or post-glacial rock-channels before it reaches the Comber valley. Gravels, composed mainly of the local slate and grit, but with a fair sprinkling of far-travelled rocks like those in the adjacent boulder-clays, and with an admixture of yellow sand, occur in several of the wider valleys in the form of flat-topped mounds abutting upon the lower slopes. Mr. Seymour.

The same features extend southward into the ground at the margin of the map surveyed by Mr. Muff, and eastward up to the Lagan valley through an area examined by Mr. Kilroe. On the slopes in the neighbourhood of the main valley, however, the boulder-clay becomes more markedly calcareous and contains many fragments of chalk. In clay of this character Mr. Kilroe has detected shell-fragments in three hitherto unrecorded localities along the course of the Purdysburn and its feeders. Mr. Muff. Mr. Kilroe.

The prevalent striæ on the hills between the Lagan valley and Strangford Lough are directed to points between S. and S.S.E.; but in a few places cross-striations were observed having an approximately E.–W. direction which are believed by Mr. Kilroe to indicate an earlier westward movement of the glaciating agent.

Mr. Lamplugh and his colleagues are of opinion that the facts above summarised are best explained by the land-ice theory. From this point of view the whole area was buried under Summary.

Summary. an ice-sheet during the period of maximum glaciation. The general movement of this ice-sheet was southward and independent of the contours of the buried land in the district, though the steeper features appear to have caused local modifications in the direction of flow. During the dwindling of this sheet, which may not have been continuous and uninterrupted, the irregular gravels of the basaltic upland and of the Silurian hills were formed by floods due to the melting of the ice, while the fine sands and warps of the Lagan valley were deposited in temporary lakes held up by the ice, and the esker-gravels mark the river-courses with which the ice was channelled.

POST-GLACIAL AND RECENT DEPOSITS.

Mr. Lamplugh. With the exception of the estuarine clays of Belfast Lough and Strangford Lough, the post-glacial deposits of the district are scanty and unimportant. The valley of the Lagan is too narrow and too deeply trenched through the drifts to permit much development of river-gravel terraces. Owing to its present sluggish course, however, its low alluvial flat is rather extensive in places. The other streams are small, and generally descend from the hills in deep gorges, around the mouths of which there is frequently a fan-shaped sheet of stony wash.

The estuarine clays were thoroughly studied by Mr. R. Lloyd Praeger when good sections were available during the construction of docks, etc.; and the work of the Survey in these deposits has been confined to the mapping of the boundaries. The "25-ft." Raised Beach, which constituted the shore-line during part of this period, is represented in one form or another throughout the coast-line of the district.

ECONOMICS.

Bricks of local manufacture furnish the chief building material for Belfast, and owing to the rapid growth of the city the demand for these has been great. Extensive brick works, fitted with modern appliances, have been established in large numbers around its outskirts, and are now sufficient not only to supply the local demand but to yield a large surplus output which is sent to other parts of Ireland. In some of these works the raw material is derived entirely from the boulder-clay, or with an admixture of the stratified 'warp' clays where these are also present; but some of the largest yards are worked deeply in the Triassic marl, though here also the boulder-clay is used where it occurs as a capping to the marl.

The glacial sands are extensively dug for building purposes and in some places for use as moulding sands. The gravels are employed for the usual purposes through the district.

The estuarine clay, locally known as "sleech," on which the central part of Belfast is built, is too soft to make a safe foundation for heavy edifices; and much expense is therefore entailed in preparing a firm platform by driving in long timber piles before building is begun in this tract.

Small patches of peat occur here and there in hollows among the Silurian hills, and there are wider tracts of no great thickness on the higher part of the basaltic upland. Numerous places were also noticed where it had once existed but had been cut away for fuel. Mr. Lamplugh.

AGRICULTURAL NOTES.

From the great variety which obtains amongst the superficial deposits in this area may be inferred a corresponding variety amongst its soils and subsoils. Commencing with those formed of boulder-clay on each side of the valley a strong contrast is noticeable between the boulder-clay soils formed upon the basalt plateau and along the eastern slope of the escarpment and those partially clothing the Silurian hills. The basalt from which the former boulder-clay has been derived has usually weathered to such an extent as to yield a stiff, retentive, cold soil, mostly under pasture, but, where drainage and liming are lacking bearing a poor herbage, including rushes, 'sprits', *Ranunculus*, *Pedicularis palustris*, and other weeds. The valuable constituents which weathering basalt imparts are overridden by the physical nature of the soil; but with drainage and liming the land is made to wear a more propitious aspect. The good quality of basaltic soils is to be seen in the parts where the rock covering is thin and the subsoil rubbly, and where in consequence the percolation is free. These are the portions selected for tillage near the summit of the escarpment. Mr. Kilroe.

The cultivation over the Silurian ground on the east side is of an advanced type; the soils and subsoils being characteristically stony, in many places even rubbly, so that the labour of tillage is comparatively small. The fine material makes a favourable seed bed, and a good receptacle for manures, and the district is favourably situated near a large centre of population for artificial treatment. The soils are probably greatly wanting in the three main constituents—lime, potash, and phosphoric acid—in available form at least, and for crops they require "full manuring."

The marly boulder-clays of the valley as well as some warp-clays interstratified with the sands, containing few stones and usually little sand, form highly retentive soils and to a large extent are under grass. The grass forms a strong thick coat, but in many places rushes appear in abundance. Some of the warp clays contain sand and form soils not difficult to till and of high quality. The more retentive warp-clays and the marly boulder clay contain carbonate of lime sometimes in large quantity, though the uppermost layer, including the soil and immediate subsoil, has become decalcified. A shallow-rooting herbage therefore cannot derive much direct advantage from these supplies, and capillary attraction which would otherwise place this valuable constituent within easy reach of the roots, is sluggish in these highly retentive clays, and in consequence fulfils its functions but feebly.

Mr Kilroe.

The gravelly boulder-clay here and there met with along the lowest part of the valley from Ballymacoss, eastward by Lisburn, forms soils well suited to tillage, but generally more under pasture than tillage. The herbage borne is of good quality, and with fair treatment these soils form excellent land. In this division we may include the sheep-walks east of Purdie's Burn, the exceptionally good land south of Dunmurry, and the grazing farms north and north-west of Lisburn.

Sands bordering the Lagan river are much availed of for market-gardening, both south-west and north-east of Lisburn. They yield themselves to tillage at the minimum of cost, form dry soils for early cultivation, and with good management can yield two crops yearly. They present a curious diversity when laid down, some bearing a good thick coat of perennial gramineous herbage, while others lose their hold on grass, and require to be kept in rotation cropping.

IV.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year:—

A. ENGLAND AND WALES.

I.—MAPS.

One-inch Maps (New Series.)

Sheet 123 (Stoke-up-Trent). Two editions, with and without Drift. By W. Gibson, T. I. Pocock, and C. B. Wedd.

Sheet 314 (Ringwood). One edition with Drift. By C. Reid, F. J. Bennett, and E. E. L. Dixon.

The following One-inch New Series Maps, previously issued hand-coloured, have been replaced by Colour-printed Maps:—

Sheets 232 and 248 (with and without Drift).
„ 249 (without Drift).

The following One-inch New Series Maps have been colour-printed, and await the publication of accompanying Memoirs.

Sheets 298 and 317. *published*

Six-inch Reference Maps.

One hundred and thirty-nine manuscript coloured copies of six-inch sheets and quarter sheets have been made from the field copies, and deposited in the office for public reference. These are as follows:—

Carmarthenshire.—41 S.E.; 42 S.W.; 49 N.W., N.E., S.W., S.E.
Cheshire.—35 N.E., S.E.; 36, 37 N.W., S.W.; 42 N.W., N.E., S.W., S.E.; 43 N.E., S.W.; 44 N.W.; 49 N.W., N.E., S.W., S.E.; 50 N.W., S.W., S.E.; 51 N.W.; 56 N.E.; 57 N.W.; 62 S.W., S.E.
Cornwall.—35 N.E., SE.; 36 N.W., N.E., S.W., S.E.; 37 N.W., S.W.; 43 N.E., S.E.; 44 N.W., N.E., S.W., S.E.; 52 N.E., SE.; 53 N.W., N.E., S.W.; 62 N.W., NE.; 65 N.W., N.E. S.W., S.E.; 71 N.E., S.E.; 72 N.W., N.E., S.W., S.E.

Derbyshire.—54 N.W., N.E., S.W., S.E.; 55 N.W., N.E., S.W., S.E.; 56 N.W., N.E., S.W., S.E.
Glamorganshire.—14 S.E.; 22 N.E.; 23 N.W., N.E.
Hampshire.—36.
London.—1 S.E.; 3 S.E., N.E.
Middlesex.—14 N.E., S.E.
Nottinghamshire.—49 N.E., S.E.
Shropshire.—3 S.W., S.E.; 9 N.W., N.E.
Staffordshire.—3 S.W.; 6 N.E., S.W., S.E.; 7 N.W., S.W., S.E.; 10 S.E.; 11 N.W., N.E., S.W., S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., S.W., S.E.; 16 N.E., S.E.; 17 N.W., N.E., S.W., S.E.; 18 N.W., N.E., S.W., S.E.; 19 N.W., N.E., S.W., S.E.; 22 N.W., N.E., S.W., S.E.; 23 N.W., N.E.; 24 N.W., N.E. S.E.; 28 N.W., N.E., S.E.
Yorkshire.—4 N.W., N.E., S.W., S.E., 131.

II.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom for 1901, pp. 219. Price 1s.

The Water Supply of Berkshire. By the late J. H. Blake, with contributions by W. Whitaker. pp. 115. Price 3s.

The Geology of the Country around Exeter. By W. A. E. Ussher, with Petrological Notes by J. J. H. Teall. pp. 122. Price 2s

The Geology of the Country around Southampton. By C. Reid, with contributions by W. Whitaker. pp. 70. Price 1s. 6d.

The Geology of the Country around Ringwood. By C. Reid, with contributions by F. J. Bennett and E. E. L. Dixon. pp. 62. Price 1s.

The Geology of the Country around Stoke-upon-Trent. By W. Gibson and C. B. Wedd. pp. 87. Price 1s. 6d.

The Geology of the South Wales Coalfield. Part 3. The Country around Cardiff. By A. Strahan and T. C. Cantrill. pp. 147. Price 2s. 3d.

B. SCOTLAND.

I.—MEMOIRS.

The Geology of Eastern Fife. By Sir Archibald Geikie, with Appendix of Fossils by B. N. Peach, pp. 421. Price 8s.

The Geology of Lower Strathspey. By L. W. Hinxman and J. S. Grant Wilson, with Petrological Notes by J. S. Flett. pp. 91. Price 1s. 6d.

C. IRELAND.

I.—MAPS.

One-inch Maps.

Revised editions of the following one-inch maps of the Geological Survey of Ireland were issued, the revision-work being generally confined to the Silurian rocks:—

Sheets 36, 48, 49, 58, 59, 60, 68, 69, 70, 71, 72, 78, 81, 82, 91, 92, 101, 102, 111, 112, 120, 121, 124, 128, 129, 130, 133, 138, 139, 144, 145, 147, 148, 149, 154, 156, 157, 158, 159, 165, 167, 168, 169, 178, 179, 180.

Six-inch Reference Maps.

Twelve manuscript copies of six-inch sheets have been made from the recently completed drift maps of the Dublin area, and are now available for reference in the office :—

Co. DUBLIN. 14, 15, 16, 17, 18, 19, 22, 23, and 25.

LIST OF EXTRA OFFICIAL PUBLICATIONS.

ANDERSON, Dr. T. and FLETT, Dr. J. S.—Preliminary Report on the Recent Eruption of the Soufrière in St. Vincent, and of a visit to Mont Pelée, in Martinique. *Proc. Royal Soc.* vol. lxx. pp. 423-445.

HILL, J. B.—The plutonic and other intrusive rocks of West Cornwall in their relation to the mineral ores. *Trans. Roy. Geol. Soc. of Cornwall.* vol. xii. p. 546.

NEWTON, E. T.—*Trogontherium* from a Pleistocene Deposit in the Thames Valley. *Geol. Mag.* Dec. iv., vol. ix. p. 385.

REID, C. — Note on the Plant-remains of Roman Silchester. *Archaeologia.* vol. lviii.

STRAHAN, A. — On the origin of the River System of South Wales, and its connection with that of the Severn and the Thames. *Quart. Journ. Geol. Soc.*, vol. lviii. p. 207.

THOMAS, H. H—The mineralogical constitution of the finer material of the Bunter Pebble-Bed in the west of England. *Quart. Journ. Geol. Soc.* vol. lviii., p. 620.

WOODWARD. H B.—Further Note on the Westleton Beds. *Geol. Mag.* Dec. iv. vol. ix., pp. 27-30 ; *Rep. Brit. Assoc.*, for 1901, p. 635.

————.—Some Railway Cuttings in Suffolk. *Geol. Mag.*, Dec. iv., vol. ix., pp. 129-132.

————.—Note on the occurrence of Bagshot Beds at Combe Pyne, near Lyme Regis. *Ibid.*, pp. 515, 516.

APPENDIX.

I. ON THE DEVELOPMENT OF CRYSTALLINE SCHISTS FROM GRANITE AND HORNFELS IN ZONES OF SECONDARY SHEARING.

BY C. T. CLOUGH, M.A.

In the course of the survey of central Ross-shire during last season, important evidence was obtained of the development of planes of schistosity by thrust movements in the granitic rock of that region and in the sedimentary strata which have been hornfelsed by that igneous mass and its apophyses.

Near a hill called Cnoc an t' Saic, which lies about two miles S.E. of the Post Office of Craigs, and about seven miles W.S.W. of Bonar Bridge, Ross-shire, there are good exposures of the augen-gneiss which has been frequently referred to in previous issues of the Summary of Progress. In some localities the augen-gneiss is represented by a granitic rock which shows no distinct foliation, containing phenocrysts of beautifully zoned felspar with indications of idiomorphic outlines. The rocks of sedimentary origin appear, in places, either as knotted hornfels or slightly schistose beds. In these localities various thrust planes have been detected, near which the rocks become sharply twisted, attenuated and deformed: indeed, the phenomena are in many respects the counterpart of those near the Pre-Torridon thrusts of west Sutherland. The hornfels near these thrusts becomes converted into mica-schists, and the granitic rocks are changed into finely foliated augen-gneisses with a granulitic matrix.

Some of the schists resulting from the deformation of the hornfels closely resemble Moine Schists found miles away from the augen-gneiss. Indeed the folding and alteration which have taken place since the intrusion of the granite seem competent to have produced the different types of schist now generally found in the Moine Series. At the same time it must be admitted that in other sections we see phenomena which suggest that the sediments may have been to some extent schistose before the solidification of the granitic rock took place.

The hornfelsed rocks, the chief areas of which are shown in the accompanying map, must originally have been muddy sediments with thin sandy laminæ closely resembling those near Kildermorie.* Where the hornfelsed character is most pronounced, they are extremely tough, hardly break along the bedding-planes and frequently contain crowds of small dark grey or pale grey spots, together with small pink garnets and thin streaks of pyrites. In those places where the spots are spherical there is nothing to show that the beds have ever been folded and the angle of dip is generally small. From rocks of this type there are gradations to others, more micaceous and schistose, containing garnets with rounded edges, and spots which are flattened and elongated in one direction, which, in places, crosses the bedding planes at a considerable angle. From the shape of the spots it is inferred that these schistose rocks were once in a hornfelsed condition, and have subsequently been exposed to movements which have rendered them schistose. As regards the hornfelsed rocks, in the special area now under consideration, it is doubtful whether any were in a schistose condition before the intrusion of the granitic rock.†

* For a description of these by Dr. Crampton and Dr. Flett see Summary of Progress for 1901, p. 101.

† See also Mr. Peach's observations in the Summary of Progress for 1898, p. 9.

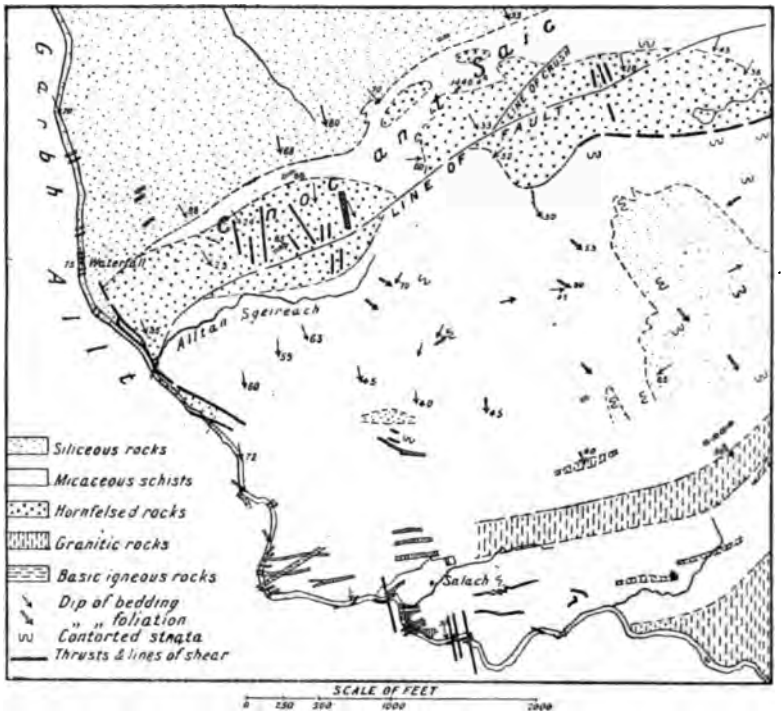

Fig. 6. *Map of country near Cnoc an t' Saic, S.W. of Bonar Bridge.*

One set of thrusts, nearly vertical and striking N.N.W. is seen on the S.E. side of Cnoc an t' Saic. (See Map). Other thrusts, almost horizontal, cross the N.E. bank of Garbh Allt rather more than half a mile S.W. of the top of Cnoc an t' Saic. Other lines of thrust striking E.N.E. probably also occur, but they are not seen in clear sections. On Cnoc an t' Saic the most distinctly hornfelsed rocks form a narrow band extending W.S.W. and E.N.E. the general dip being S.S.E. at an angle of about 25°. Thin strips of schistose rock, produced by the thrust movements, cross this belt in a N.N.W. direction.

The vertical thrusts striking N.N.W. are also well seen in Garbh Allt, where they affect both the sediments and the thin sheets of granitic rock. In the accompanying diagram (Fig. 7) the vertical thrust traverses micaceous schist, the latter being shown on left side of drawing. Away from the thrust the strike of the schist is about E.N.E., but on approaching it the bedding planes become nearly vertical and are much attenuated. In the line of the thrust the sharp folds in the schist are faintly visible, and new planes of schistosity are developed parallel to the plane of vertical movement and the axial planes of the folds. The newer schistosity almost effaces the original planes of bedding.

On the N.W. and S.E. sides of the band of hornfels on Cnoc an t' Saic just referred to, there are schistose rocks, generally dipping S.S.E., like most of the members of the Moine Series of the neighbourhood. The schists on the S.E. side show indications in places of having once been in a hornfelsed condition, but their knots or spots are now often deformed. Both the N.W. and S.E. boundaries of the band on Cnoc an t' Saic are tolerably sharp, and they appear to represent lines of contortion accompanied in places with thrusting. The movements which gave the E.N.E. strike are of special interest, as this is the most common strike of the Moine schists over a large district. In the schists on the N.W. and S.E. sides of the hornfelsed band of Cnoc an t' Saic no thrusts striking N.N.W. are seen, but in some places the strike suddenly twists into a N.N.W. direction. It seems probable, therefore, that the movements which produced the N.N.W. strike and the N.N.W. thrusts are of the same age, and later than those which gave rise to the E.N.E. strike, —the latter being the general strike of the Moine schists of the district.

It is probable, also, that the movements which produced the almost horizontal thrusts are later than those which gave rise to the E.N.E. strike. Near one of the thrusts in the Garbh Allt, the garnetiferous mica schist, a little S.E. of the section where the thrust is exposed, is thrown into folds with nearly horizontal axial planes, and it seems clear that the rock was already in the form of schist before such folding was developed. We know, too, that in various places far away from the augen-gneiss, there are almost horizontal planes of movement which cut both the bedding and foliation of the adjacent Moine schists at considerable angles; and that along these planes we see, in places, crumpled chlorite schist, no doubt representing an intrusive rock, in which the general direction of foliation is parallel to the plane of movement.

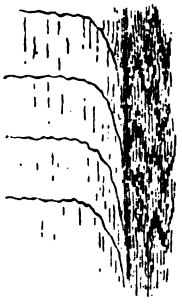

DIAGRAM SECTION OF VERTICAL THRUST IN GARBH ALLT

FIG. 7.

Nowhere in the area now being described are the most distinctly hornfelsed rocks seen in contact with the augen-gneiss; indeed they are often separated from it by schists in which the hornfelsed character is not observable. This may, perhaps, be explained on the supposition that near the edge of the intrusive rock there has been more differential movement since the period of hornfelsing than further off.

The rocks of sedimentary origin which are in contact with the granitic rock are not all equally schistose; some are but slightly so and contain small spots of biotite. Where the latter are in contact with it, the granitic rock is also less foliated than usual, or even free from foliation. Both the less schistose Moine

rocks and the bands of granitic rock in contact with them are in the Garbh Allt, crossed by vertical thrusts striking N.N.W., and along these thrusts both the Moine sediments and the intrusive rock become very micaceous and schistose. It is clear, therefore, that at all events in some parts of the granitic rock the foliation or schistosity is secondary, and due to the causes which produced, or intensified, the schistosity in the altered sediments.

Various other phenomena agree with this conclusion. On Carn Salach,—a hill about a mile and a half S.E. of Cnoc an t' Saic,—within the augen-gneiss various thin strings of fine grained pink rather acid rock occur, in which the foliation planes make an angle with the margins, and continue outside these margins, to form the common foliation planes of the augen-gneiss.

On the north side of the pass N.N.W. of Carn Salach, thin strings of augen-gneiss are mixed with Moine schists, and both have been folded into isoclines with nearly vertical limbs. The Moine schists and granitic rock are very micaceous, finely schistose, and granulitic. The former contain much white mica, perhaps produced from felspar during the shearing process. In one thin strip the planes of foliation or schistosity cross the margin clearly, and are parallel to the axial plane of fold and the corresponding planes in the Moine schist. At other localities, for instance in the Garbh Allt, bands of granitic rock appear which are crossed by foliation planes making considerable angles with their margins, and in some instances parallel secondary foliation planes are also visible in the adjacent Moine schists.

In the places just referred to, the first foliation planes in the Moine schists are not highly developed, but they do exist, and it is a little doubtful in some cases whether any planes corresponding to them occur in the intrusive rock, so that the appearances suggest that the sediments may have been to some extent schistose before the intrusion took place.

This is also suggested by the occurrence of various granitic intrusions, with blue quartz blebs and no distinct foliation, in garnetiferous mica schist in the Garbh Allt, rather more than half a mile S.S.W., of the top of Cnoc an t' Saic. It is possible, however, that the intrusive rock may have continued in a liquid state for a very long period, and that during this time the sediments were in places folded and made schistose.

II. Note on some Brecciated Stanniferous Veinstones from Cornwall.

By JOHN S. FLETT, M.A., D.Sc.

In connection with the work of the Geological Survey in Cornwall, which involves an investigation of the tin-lodes of that area, Mr. Donald A. Macalister has, at the request of the Director, collected a series of specimens of the tin-bearing veinstones, which have been sliced and subjected to microscopic examination.

The material was obtained from four different mines, viz. —Dolcoath, Wheal Basset, South Crofty and Carn Brea; and Mr. John Scrivenor has obtained tin-ores from two others, viz.— Wheal Kitty and West Kitty; the results of his examination of these specimens are included in this note.

The veinstones differ a good deal both in appearance and in composition, but many of them are hard, splintery, dark-blue or dark-green, fine grained rocks, in which the brown colour and somewhat resinous lustre of fine granular disseminated tinstone can be observed, and in some cases the splendent faces of well developed crystals are visible on the surface of the hand specimens.

Some of these veinstones are typical breccias,* easily recognised as such by the naked eye, and contain angular or sub-angular fragments of white milky quartz, embedded in a matrix which is fine-grained and dark green or bluish-green in colour. This dark matrix is known to the miners as "peach," and, while in some cases it is so fine as to be cryptocrystalline in appearance, in others it is visibly composed of little acicular needles.

Others of these breccias are difficult to recognise at first glance, though essentially similar in structure to those just described, for the quartz fragments may be small, clear and transparent, and from the dark colour of the matrix and its abundance, they are very inconspicuous. Microscopic examination, however, leaves no room for doubt regarding their nature.

The matrix also, in which the quartz fragments lie, is very often itself a breccia in which broken masses of the dark, splintery "peach" are held together by a substance which closely resembles the fragments, but differs from them slightly in colour or in coarseness of grain.

Veins of white quartz frequently cross the brecciated veinstones at all angles, and these occasionally contain copper-pyrites. Tinstone does not occur in these latest veins.

It will be seen that the structure of the hand specimens indicates a complex history for these veinstones. They have apparently been produced by repeated processes of infiltration by mineral solutions, alternating with periods during which movement has taken place along the walls of the vein, and in

*That many of the tin lodes of Cornwall are brecciated is a fact which has long been known and has attracted a good deal of attention. Descriptions of individual cases will be found in the following papers among many others :—

Notes on New Rosewarne Mine. By C. Le Neve Foster. *Trans. Miners' Assoc., Devon and Cornwall*, 1866, p. 26.

On some Cornish Tin-stones and Tin-capels. By J. H. Collins. *Min. Mag.* Vol. iv., p.l. 1880.

Remarks on some Tin Lodes in the St. Agnes District. By C. Le Neve Foster. *Trans. Roy. Geol. Soc. Cornwall*, Vol. ix., Pt. iii. 1877.

The Lode at Wheal Mary Ann. By C. Le Neve Foster. *Ibid.* Vol. ix. p. 156, 1878.

Observations on the Rich Parts of the Lodes of Cornwall. By L. Moissenet, translated by J. H. Collins. 1877.

On the Metalliferous Deposits of Cornwall and Devon. By W. J. Henwood. *Trans. Roy. Geol. Soc. Cornwall*, Vol. v. 1843.

this way masses have been deposited in the fissure which have at a later period been broken up and re-cemented by a fresh deposit, to be again shattered by renewed movement, and finally again consolidated into a firm, coherent mass. The microscopic examination of the specimens entirely confirms this view.

Microscopic Characters of the Veinstones.

The essential constituents of these tin-ores are quartz, tourmaline, chlorite and tinstone. Fluorspar, pale micas, iron oxides, copper pyrites, kaolin(?) are present also, but not universally, and occasionally there are pieces of altered felspar, and fragments of granite or of slate. The foreign ingredients, however, have usually been decomposed or impregnated with new minerals by the agencies by which the fissures were infilled, and their original characters have been largely modified in consequence.

Dolcoath.—Three samples of the material which was being crushed at Dolcoath mine during June, 1902, were sliced and examined. They were all quartz tourmaline breccias containing grains and crystals of cassiterite. All came from the 375 fm. level, where the country rock is granite. Of these specimens two consisted of broken fragments of quartz embedded in a finer-grained matrix of quartz and tourmaline. The third contained many aggregates of pale mica which appear to be altered remains of felspar, no doubt derived from the country rock, and in this specimen the "peach" was green, owing to the abundance of finely divided chlorite, while tourmaline was present only in small quantity.

The quartz fragments of the breccia vary in diameter from one inch downwards, but are mostly very small; they are full of fluid enclosures with mobile bubbles, and may contain also small transparent, colourless, isotropic grains, which are apparently to be referred to fluorspar. These often show traces of cubical crystalline form. The quartz of the larger grains is shattered and broken, and, when viewed between crossed nicols, exhibits very often a perfect cataclastic structure, with undulatory extinction and all the characteristics which are produced by the breaking down of this mineral under severe pressures.

The quartz of the matrix or "peach" is finely granular, and there can be no doubt it has in large part resulted from the grinding up of the crystalline quartz which first filled the vein, and of which the larger fragments represent the less altered residuum. But it is also clear that after the shattering of the first material which entered, a fresh mineral deposit was laid down which healed up and firmly compacted the broken mass, and of the minerals introduced at this time quartz was one of the most important.

Tourmaline is the mineral next in abundance to quartz. It takes the form of large, rounded, fissured, often broken grains, which are usually brown in their centres and blue on their edges and cracks, and of minute narrow, elongated prisms, always blue in colour, scattered through the quartz of the matrix. These frequently show rhombohedral terminations and hexagonal transverse sections, but the larger grains and many of the smaller needles are without crystalline faces.*

The tinstone resembles the tourmaline in the manner of its occurrence but forms rounded grains and short double pyramids in place of the long needles of the former mineral. The chlorite is in small irregular scales, pale green and greenish yellow, distinctly dichroic, and yielding grey polarisation colours of the first order even in very thin sections. With it is associated a pale bleached mica. The chlorite occurs in the matrix with the tourmaline, and forms a dark green, fine-grained "peach" which differs from the tourmaline-bearing variety in its colour and in being so much softer that it is easily scratched with a knife when it is richest in chlorite.

*Figures and descriptions of the blue "peach" of the Dolcoath mine will be found in Mr. Collins's paper, "On some Cornish Tin-stones and Tin-capels." *Min. Mag.* Vol. iv. 1880.

A study of the sections demonstrates that the history of this rock has been as follows: A fissure opened and was filled with crystalline quartz which seems to have been accompanied by tourmaline, tinstone and fluor-spar, as all these are to be found in the interior of fragments of this first quartz deposit; and as the tourmaline and tinstone are in large crystals quite different from those of the latter infiltration, there can be little doubt that they belong to this early period. Moreover in certain cases both tourmaline and tinstone are rounded and broken, in the same manner as the adjacent pieces of quartz. Fine needles of tourmaline lie scattered through the quartz, and while the large rough broken grains are always brown in colour, these needles are invariably blue. They may be in part of the same age as the quartz, but as they are always crowded together near the edges of the fragments, where they form a transition to the surrounding peach, which is filled with similar needles, it is likely that such tourmaline is to a large extent of later origin and belongs to the second period of mineral infiltration.

After the vein had been filled with a coarsely crystalline mass of tourmaline, quartz and tinstone, movement set in and the vein rock was crushed into fragments varying in size, embedded in a fine granular broken-down matrix of similar composition. The second period of infiltration ensued; the porous, granular, ground-up quartz between the fragments of the breccia was filled with radiate clustered needles of tourmaline, and recemented by fresh quartz to form a hard coherent rock. In this way the dark blue "peach" originated. Fluor-spar and tinstone were also introduced at this time, as they occur in the "peach" in such a way as to show that they accompanied the fine needles of blue tourmaline.

Apparently the material entering the fissure in these two periods was essentially similar in composition and left a deposit of the same minerals, though probably not in exactly the same proportions. The blue "peach" is very rich in tourmaline and contains less quartz than the older fragments of the breccia, which are in consequence much paler in colour than the matrix in which they lie. The first tourmaline was brown, the later tourmaline blue, and often the older crystals are surrounded by fringes of blue needles, which sometimes also line the cracks which were produced by the fracture of the larger brown masses during the epoch of earth movement which intervened between the periods of deposition.

The order in which the minerals crystallised was apparently the same in both cases. Tourmaline, tinstone and fluor-spar are always surrounded by quartz, which we may infer was the last mineral to be deposited. Only very rarely do we find that tinstone encloses tourmaline or *vice versa*, and both were probably early minerals and perhaps contemporaneous. The later solutions passing through the fissure may perhaps have been able at some time to attack the surface of the quartz fragments, as these not unfrequently seem corroded and rounded by some such process, but subsequently a fresh layer of quartz full of tourmaline needles was laid down upon their surfaces.

The last stage in the history of the tourmaline quartz breccias of Dolcoath was the renewal of earth movement with consequent disrupture of the veinstones. Cracks were formed into which a third infiltration penetrated, but this time it consisted principally of quartz with little tourmaline, and formed pale quartzose veins which cut across the dark "peach" and are very distinct from it in appearance. These last veins contain no tinstone, so far as can be made out from the specimens collected, and their quartz is granular crystalline, and shows no trace of having been subjected to movement and granulitisation.

From Wheal Basset (Flat Lode, 240 fms.) Mr. Macalister obtained several specimens of tin ore which show all the essential features of that described from Dolcoath. Fragments of clear quartz lie in an abundant matrix of dark blue "peach" very rich in minute prisms of tourmaline and containing also grains and crystals of tinstone. This "peach" has itself been broken up and the mass recemented by a paler coloured and more quartzose material in which there is less tourmaline. Finally the reconsolidated veinstuff has again been fissured and narrow, white quartz veins in which tourmaline is not common have filled up the cracks.

We have in this case four periods of infiltration, separated from one another by three epochs in which the material deposited in the vein has been fractured and in some cases ground up by movement of the walls on one another, and the history of the infilling of this lode may be summarised as follows:—

I. Opening of the fissure.
II. Infiltration of quartz, tinstone and tourmaline.
III. Brecciation of the veinstuff by movement.
IV. Formation of the "peach" by infiltration of much fine blue tourmaline, with tinstone and quartz.
V. The "peach" was shattered by renewed earth movement.
VI. The broken mass was healed up by deposit of fine quartz with tourmaline and tinstone.
VII. Renewed formation of fissures, this time on a smaller scale and not attended by severe detrition of the materials filling the vein.
VIII. The fissures were filled with fine quartz almost free from tourmaline. Coppery pyrites occur in these last veins and may have been introduced along with the quartz. There is no evidence that tinstone was deposited at this period.

It will be seen that the minerals deposited in stages II., IV. and VI. are essentially the same, and there is no reason to believe that a very long time elapsed between them. Tourmaline was present in all stages and so also was quartz, but tinstone belongs to the early history of these veins and copper pyrites to the last. Movement had almost ceased when the latest quartz veins were formed, for they are never brecciated and granulitised like the earlier. The fissures must have opened after the consolidation of the granite of the walls, but there is much reason to believe that the veinstones are to be regarded as dating from a time when the granite mass had not yet completely cooled, and the fissures served as passages along which heated solutions derived from the granite were freely circulating.

Carn Brea.—The specimens from Carn Brea tell much the same story. The "peach" which surrounds the fragments of the first quartz here also has been brecciated, and the pale quartz which healed up the shattered mass is full of large tinstone crystals (belonging to period VI.). This quartz contains little tourmaline, and the tinstone, which is perfectly idiomorphic, has been deposited first, the quartz at a somewhat later period sealing up the vein. There is no evidence from the samples that a still later series of movements, followed by infiltration (VII. and VIII.) have affected this vein.

In some of the veinstones chlorite accompanies or in large part replaces the dark blue tourmaline of the "peach." It is in pale green, pleochroic scales, usually arranged in radiate groups, is strongly dichroic, and has a high double refraction for this mineral. It is abundant in the specimens obtained from the South Crofty mine and occurs also in some of the tin ores from Dolcoath. What relation it bears to the tourmaline is not quite clear from the sections, but both are apparently primary, as there is no evidence that the chlorite has formed from the decomposition of any other mineral in the vein. Sometimes tourmaline and chlorite belong to the same period of infiltration, in other cases the chlorite belongs to one period, the tourmaline to another.

Pieces of the country rock, which in all the veins examined was granite, are present also and are invariably much altered and inpregnated with tourmaline and quartz. The felspar is often entirely converted into an aggregate of pale micaceous scales, which may be infiltrated with iron oxides. Pseudomorphs in quartz and tinstone after felspar are also to be found In other cases a very fine-grained aggregate which may be kaolin has been formed. The same solutions as introduced the tinstone evidently attacked the felspar, converting it into a variety of secondary products, and partly removed these, depositing quartz and cassiterite in their place.

From West Kitty and Wheal Kitty, in the St. Agnes district, Mr. John Scrivenor has obtained specimens of the tin-bearing veinstones, which he has examined under the microscope, and the following particulars regarding them are extracted from his notes. Brecciation of the walls of the fissure, which undoubtedly occurs in this district, is not well shown in the slides. The constituent minerals are the same as those described, but in the ores from Wheal Kitty a few grains of blende are to be found. The cassiterite occurs as prisms, with the crystal boundaries poorly defined, as irregular masses of small granules, as botryoidal masses of such granules and as spherulitic groupings of thin radiate prisms. The tourmaline is in small blue prisms, embedded in quartz. Fragments of altered "killas" are found in the ore from Wheal Kitty. They are filled with small grains of tourmaline, which are all brown in colour, and contrast strongly in this respect with the blue tourmaline of the "peach." On the surface of those fragments a later growth of tourmaline has sometimes formed in blue acicular prisms, which point outwards towards the centre of the vein.

III. Remarks on the Devonian and Caboniferous Rocks in South Devon and Cornwall.

By W. A. E. USSHER, F.G.S.

In order to complete the Dartmouth slate boundaries, and to compare the Devonshire coast sections on the north of the Dartmouth slates with those on the south, some field work in Devon was carried on during the early part of the year.

This investigation was rendered necessary by the results obtained in East Cornwall some years after the districts in question had been surveyed, and to supply indispensable data for the completion of the Memoirs, explanatory of Sheets 350, 355, and 356.

DEVONIAN.

In the *Summary of Progress* for 1899 (p. 85), the inconclusive character of the evidence as to the position of the Looe fossiliferous beds in the Lower Devonian succession in East Cornwall, is pointed out. In the *Summary* for 1900, p. 60, reasons are given for placing the Looe beds above the Dartmouth slates on the ground of the occurrence of fossils of characteristic Looe types in the Torquay and Paignton Lower Devonian anticlines (in which the Dartmouth slates are not exposed).

In the *Summary* for 1901 the occurrence of a calcareous fossiliferous series in the lower part of the Meadfoot group, corresponding in character to the Looe rocks, and in faulted junction with the Dartmouth slates in the Plymouth coast section, is pointed out.

To complete the stratigraphical evidence, the coast section on the south of the Dartmouth slates had to be brought into direct comparison with the East Cornwall and Plymouth coast sections, and with the coast section south of Berry Head.

One of the chief factors in this investigation has been the occurrence of lenticular grey and red strings and patches of limestone on the East Looe, Millendreath and Tregantle coast. These limestones are often crowded with white, irregular patches of calc spar, which, in shape, suggest the presence of Monticuliporoid corals. This character is by no means uniformly present in the limestone films and lenticles associated with the rocks of Looe (the majority being crinoidal), but, where present, it accompanies the fossiliferous beds, and is easily recognisable. It occurs in the Plymouth coast section, and, in the following notes, will be referred to as the Monticuliporoid type. Stress is laid on this type as the Brachiopods proved too imperfect for identification, time not permitting a protracted search.

Bigbury Bay Section.—At Hoist Point the Dartmouth slates contain quartz-albite (pegmatite) veins. At four chains east from Westcombe Beach their reddish, glossy slates are in (probably faulted) junction with dark slates, locally interbanded with pale silty material, and containing occasional beds of grit. These slates (locally stained reddish) give place to an interbanded

series, with some hard beds of grit and films of crinoidal limestone containing large ossicles as at Tinsey Head. In places the limestone films are of the Monticuliporoid type, and the dark grey colours give place to red. In this series a small thickness of red and dull greenish papery shales with brown fossiliferous films containing crushed Brachiopods and Zaphrentid corals, represents the usual fossiliferous type of the Kingsbridge and Ringmore districts.

The red-stained calcareous beds give place to dark grey slates or shales, with occasional crinoidal films containing *Zaphrentis*, and a fossil also found in the dark slates of Crownhill Bay in the Plymouth section. In these beds in the reefs on the north side of Ayrmer (or Armour) Cove there are hard dark patches, in one of which Mr. Brook-Fox discovered unmistakable *Pteraspis* structure.

On either side of Ayrmer Cove the dark slates contain in places pale yellow-green bands of igneous rock, occasionally with vesicles filled with calc-spar. They also exhibit the pale, straw-coloured variegation so characteristic of slates in the Falmouth district.

On rounding Toby's Point the slates contain dark structureless patches and quartz veins in places, resembling gnarled bedding (so well shown in the Torcross section). The dark colours give place irregularly to red, and the red in one place is anticlined over grey at the base of the cliff. Igneous bands, one of which is evidently folded, are then visible in dark grey, partly reddish, slates containing hard lenticles occasionally suggestive of *Orthoceras*.

The projecting headland south of Toby's Point is chiefly composed of hard, reddish, silty shales apparently disposed in a low anticline and exhibiting a gnarled structure. In these beds red crinoidal limestone films were noticed, and also decomposed brown bands, probably of igneous origin. Further on the red colour gives place to grey. Approaching Challaborough dark grey slates, with or without silty interbanding, when traced on their strike from the beach-reefs, become red in the cliffs, the grey colour sometimes persisting upward to the surface. These rocks are identical with those of the Torcross section, and contain in places impersistent bands of pale sheared igneous rock, never more than three feet in thickness and probably repeated by plication and shifted by small faults or strain cracks. Traces of fossils, mostly replaced by pyrites, are met with. The same mineral is developed on brown-bed bands, and veins of quartz and carbonate occur in the slate, near Challaborough.

At the north end of Challaborough sands a fault, marked by a W.N.W. and E.S.E. channel in the beach-reef, throws dark grey and red (ologiste) splotched slates against red slates or shales with gritty bands (of the Ringmore type).

Between Challaborough and Warren Point the rocks are identical in character with the slates of Toby's Point, the grey

and straw-coloured variegation and irregular reddish staining in mass being equally noticeable, also the local occurrence of hard lenticles. There are occasional igneous bands resembling a type met with at Darnacombe as well as the Torcross type. South of Warren Point the rocks belong to the same series, the red tints sometimes following the strike, as at the south end of Borough Island. Signs of fossils were noticed on Borough Island near the Pilchard Inn. At the Fish cellars hard igneous rock occurs in red slates or shales.

Between Sedgewell Cove and Sharpland Point red, purple, and grey mottled shaly rocks with brown decomposed fossiliferous seams may be taken as a repetition of the Ringmore fossiliferous beds. Between Sharpland Point and Cockridge Point (at the bend in the Avon) the slates contain much quartz, beds of compact grit or quartzite, interlaminated beds, and a mass of igneous rock with fretted weathering, in shales with red limestone seams, mostly crinoidal, but in part of the Monticuliporoid type. Near this we encounter Dartmouth slates, their purple almost immediately giving place to reddish tints. These slates at Cockridge Point contain *Pteraspis* and hard grit beds, some of which resemble the *Pteraspis* grits of Portwrinkle, etc., in Cornwall. Quartz-albite veins are noticeable at Cockridge Point. The occurrence of this inlier was considered probable but never absolutely proved before.

From Hoist Point to Avon mouth, the fossiliferous Ringmore beds are shown to be of no great thickness. So that the evidence of a broad belt of strata, called the Ringmore group, in which the fossils accompanying similar lithological types recur, is clearly due to plicated repetition.

Toward the mouth of the Avon the Dartmouth slates, probably with fossiliferous beds of the Ringmore type, are concealed by the river sands under which the anticline noses out westward. On the south of the Avon the grey and greenish-buff variegated slates in the cliffs of Hams Sand are a repetition of those of Aymer Cove and Challaborough. In the beach reefs, a large *Pleurodictyum* was found at the south end of Hams Sand. Toward Longstone the section is similar to Torcross, pale masses or bands of igneous rock occur in grey slates with even silty interlaminations in places. Traces of crinoidal limestone (in one spot Monticuliporoid) were detected near Longstone Promontory.

Longstone promontory is composed of red silty shales or slates with beds of grit interpenetrated by quartz; traces of fossils are found in these beds near the coast.

South of Longstone the red colour gives place irregularly to grey, and the section resumes the Torcross type, with the grey and green sheared igneous bands and the irregular grey and red colouring displayed near Toby's Point and Challaborough. Crinoid stems and traces of Brachiopods were noticed in grey slate with silty lenticles near a band of igneous rock at the point on the south of Yarmouth Sands. On the north of the Thurle-

stone outlier 3 feet of greenish igneous rock occurs in grey brown-banded slates or shales with silty lenticles. Here are also several beds of breccia, probably of volcanic origin, as the traces of shearing seem insufficient to account for them. The rock reefs on the south of Thurlestone sands on which the well-known outlier rests, consist of soft silty grey and reddish slates, and in them also traces of igneous rock are present.

From Thurlestone Cottage to the brown rocks of Hope Headland the section displays no signs of igneous rock. Dark grey slates, locally becoming reddish, with *Zaphrentis* and crinoids in places, make an unsatisfactory junction at Beacon Point with red grit and hard silty slates (containing hard carbonate) with crinoidal lenticles. These gritty beds are overlain by slate with siliceous limestone and hard carbonate bands and nodules and interlaminated beds of the Tinsey Head type. Between Beacon Point and Woolman's Point grey slates, with partly calcareous lenticles and red films, are intersected by quartz veins and overlie a small patch of the interlaminated rocks faulted up at the base of the cliff near Beacon Point. At Woolman's Point a fault brings on silty and calcareous interlaminated beds, succeeded by slates with some hard carbonate veins, thin red films, and very occasional limestone lenticles.

At Mouthwell, the hard silty beds of Beacon Point reappear in plicated association with dark slates containing hard carbonate nodules. There can, therefore, be little doubt that the Beacon and Woolman's Point beds are repeated at Mouthwell, and that the dark slates overlie them. The only question is whether they are above or below the slates on the north. If below, they must be an anticlinal repetition of the Longstone promontory and Ringmore beds. If above, they are the outcrop of a series of grits, which, from their greater development inland and at Beesands, are probably, to a great extent, cut out by fault at Beacon Point. In this case the slates with igneous rocks are lower in the series than those south of Thurlestone Cottage. The east coast section from Hall Sands northward throws little additional light on this question, favouring, if anything, the latter view.

Torcross Coast.—In this section the interlaminated beds of Tinsey Head correspond to those of Woolman's Point, and are repeated in an anticline in dark slates on the south. The crinoidal films of Tinsey Head resemble those near Ayrmer Cove, but no Monticuliporoid traces were discovered in them. Near Beesands, interlaminated beds accompany slates containing beds of hard grit. These upper beds are, unfortunately, the only part of the Beeson grits exposed. The slates of Sunnyvale (without igneous rocks) correspond to those between Beacon Point and Thurlestone Cottage. The succeeding rocks of the Torcross Section are the same series as those of corresponding character between Thurlestone Sands and Ayrmer Cove. The fossiliferous Ringmore horizons are scarcely exposed on the border of Slapton Ley, and

their junction with the Dartmouth slates is not visible on the Strete Gate coast, and is extremely indefinite inland.

Coast Section South of Brixham.—At 32 chains from Sharkham Point, volcanic rocks of the Middle Devonian are in faulted junction (inaccessible from the beach) with the Staddon grits. The contorted red grits, slates, and sandstones of this series are succeeded by grey slates at 10 chains from the fault. These slates are probably the upper horizon of the Meadfoot beds, and 3 chains further on assume reddish tints and are intercalated with beds of hard fine-grained grit, which also form more or less lenticular even-bedded masses.

The grits are often thick-bedded, and occasionally exhibit hard, brown, friable surface-patches with fossil cavities. In their prolongation from the north of Southdown cliffs toward Raddicombe, *Homalonotus* was found in a surface fragment. Without this discovery, their correlation with the fossiliferous *Homalonotus* grits, exposed in the New Drive (Torquay Promontory), is extremely probable. They are much plicated, and the argillaceous rocks interbedded with them have escaped cleavage.

These beds are succeeded by pale reddish and grey slates in which contorted bedding is shown in places crossing the cleavage planes. Brown bands of decomposed Crinoidal limestone are visible near 2 feet of red-brown sheared igneous rock. Dark slates with hard nodules, often crowded with small cubes of pyrites, and in places mottled with red (ologiste) splotches, occur for 6 chains to the termination of the cliff near Man Sands Cottage.

On the south of Man Sands the section continues with dark slates, with harder silty interlamination in places, resembling the Torcross beds. On the south side of Crabrock Point this resemblance is further strengthened by the occurrence of greenish igneous rock in dark slates near a fault. We then encounter grey shales or slates with silty bands and seams of Monticuliporoid limestone, followed by red shales or slates with Crinoidal limestone films. These are evidently an anticline of the Looe and Ringmore calcareous fossiliferous beds. Dark slates with green igneous bands, no doubt a repetition of those on the north, come on, giving place at the projection of the coast (10 chains south of Crabrock Point) to a repetition of the shales with Monticuliporoid limestone films.

At the north end of Long Sands, slates with dark patches similar to those at Ayrmer Cove, revealed *Pteraspis* structure, confirming Mr. Brook-Fox's discovery. Interbanded slates and silty beds here occur in the slates, and a Favositid coral replaced by quartz was obtained near their plicated junction with the grits of Long Sands. These grits consist of hard, dense, rather thick-bedded fine-grained, arenaceous rocks or silty greywacke, in which numerous pieces of shale were found along a thin

horizon. On the surface of one of the beds hæmatitic patches showed numerous traces of small fossils, perhaps gasteropods In the broken receding cliff hard grits and reddish slates occur. At 6 chains from the south end of Long Sands, the grits are in contact with dark slates with red (ologiste) blotches, and these, at the south end of the Sands, give place to dark slates or shales with hard dark patches (similar to those at the north end of the Sands) and with limestone films containing crinoids and *Zaphrentis*. Here, again, we have a resemblance to Ayrmer Cove. A thrust fault, apparently of no great magnitude, occurs here.

The cliff bounding Scabbacombe Sands is composed of dark grey slates, occasionally with pale silty interlamination and bands of grit. At the South end of the Sands a mass of red Monticuliporoid limestone (identical with similar masses on the East Looe Coast) has fallen from the cliff. The cliff, as far as accessible, consists of reddish slates and shales with beds of grit and seams and bands of crinoidal and Monticuliporoid limestone, often decomposed to brown friable residua. The grit fragments on the summit contain traces of Brachiopods.

The junction of these beds (included in the Dartmouth Slates when the district was surveyed in 1890) with the Dartmouth Slates is about 10 chains south of Scabbacombe Sand, where the cliffs are inaccessible. Near this, a band of sheared igneous rock occurs in the Dartmouth Slates. It is probably sheared tuff, similar to the beds at Brookhill near Kingswear, and to bands in the same series near Hoist Point in the Bigbury Bay section.

The identity of the rocks in this coast section, south of Man Sands, with those of the Bigbury Bay and Torcross sections, admits of no doubt. The position of the Long Sands grits, from their character and proximity to slates with *Pteraspis*, is doubtful; as a syncline they would be represented by slates in these sections; as an anticline by the Ringmore beds. Viewed, however, in connection with the Looe area, the impersistent development of such grit masses in these strata is by no means peculiar. The dark slates with nodules at Man Sands may correspond to similar beds at Toby's Point and elsewhere in the Bigbury Bay section. The distribution of the igneous bands differs, as might be expected, in all the sections, and there is very feeble evidence of their occurrence (on the north side of Crownhill Bay) in the Plymouth section.

The effect of the above conclusions on the progress of the work in East Cornwall cannot be overstated. The fossiliferous rocks of Pencarrow Head and Fowey lie to the south of the Dartmouth Slates, and the St. Austell Granite crosses the strike along which, if a persistent outcrop, they should be prolonged to Watergate Bay.

During the latter half of the year, the write was engaged on the survey of the Bodmin Road, Braddock, Boconnoc, and

Lostwithiel district. The rocks mapped, in descending order as we proceed from north to south, consist of:—

Middle Devonian including Eifelian.	Argillaceous slates with silty banding near their junction with the Lower Devonian. Further north, toward the Bodmin Moor Granite, hard dark grey slates with beds of Peek Hill type are met with.
Lower Devonian, including the representatives of the Staddon Grits and Meadfoot and Looe Beds.	Pale silty and soft shaly sandstones with hard grits, slates, and shales. Their boundary with the Eifelian runs in a north-westerly direction by Braddock (Broadoak) to Castle Canyke (near Bodmin). Owing to absence of exposures and the plicated repetition of junction beds, its position is often uncertain. The southern boundary of these rocks can seldom be mapped. They give place southward to the Slates, with occasional silty films and beds of grit of the Meadfoot Group, which includes the Looe Beds (of the type of Lanreath and Trelawne). Fossils of Looe types, but badly preserved, were found at Tawell and other places east of Lostwithiel.

The eastern border of the St. Austell Granite near Lostwithiel is included in the area. The limit of metamorphism is between a mile and three-quarters of a mile from the Granite. Amongst the spotted altered rocks are bedded hornstones of the Peek Hill and Brent type. They are due to the presence of fine calcareo-siliceous sediments or siltstones associated in the rocks of the Meadfoot Group, probably with local traces of igneous rock. Of the latter, the Railway Cutting at Trap Wood north of Lostwithiel affords an example, a sheared pale greenish rock similar to a type common in the Torcross, Thurlestone, and Kingsbridge estuary sections. These traces can only be recognised in actual exposures. A patch of coarse greenstone has been mapped near Brownqueen. A hard dark massive rock, apparently altered diabase, occurs within the limit of alteration at Maudlin.

The porcellanised rocks are quarried near Lostwithiel and in Ford Plantation south of Lanhydrock. They are sometimes banded in light and dark tints. In Brownqueen Wood hard dark rocks are locally developed in dark slates.

In the Eifelian Slates also hornstones are developed irregularly amongst dark slates. The igneous rocks in the vicinity are much weathered felsitic intrusions, occurring west of St. Neots on Goonzion Down and further west near Galgeth and Higher Hill Farm. These Elvans cannot be traced far continuously on the surface. Further south, above the Fish Pond in Glynn Grounds, an Elvan is exposed by the private drive, beyond which it cannot be traced.

Whilst inserting boundaries for the Lower Culm rocks near Newton Abbot, the porcellanised type of metamorphism which occurs near Ilsington was traced to the alteration of fine mudstones in the Upper Devonian. This type of alteration was first distinguished by Champernowne, who described the rocks near the granite of South Brent on his map as "Banded porcellanised felspathic rock" and appends "Axinite" to one of the observations. The same type occurs near Wrangaton, at Ivybridge, and near Dousland and Walkhampton. The rocks occur on the summit of Peek Hill near Dousland, from which the type name is taken

Banded rocks of a similar type found at Coddon Hill and elsewhere in the Lower Culm induced the writer during the survey of the Brent area in 1895, to regard the occurrence of this type on the borders of Dartmoor as a proof of the presence of that horizon.

The observations made during 1902 near Ilsington, in Devon, and in Cornwall prove conclusively that the type is not confined to any particular horizon, but exists wherever sediments of a certain texture occur in the strata and varies with the association of calcareous bands, volcanic materials and intrusive rocks in the fine sediments.

The Cox Tor and Sourton rocks investigated by General MacMahon, and the Peek Hill rocks described by Mr. Teall in the Annual Report of the Geological Survey for the year 1896, pp. 51 and 52, occur in an area where volcanic rocks are associated with both the Devonian and Lower Culm Measures, hence the prevalence of the igneous type. At Brent the Volcanic rocks are presumably of Middle Devonian age, in both cases the occurrence of fine-grained calcareous sediments is highly probable. That the Upper Devonian slates and mudstones of Ilsington should have been locally somewhat calcareous or indurated by igneous intrusions is also probable. The local presence of calcareous bands and calcareous siltstones in the Middle Devonian and Lower Devonian (Meadfoot and Looe beds) is characteristic.

The same type of alteration has been noted at Camelford and in one spot on the east margin of Bodmin Moor; in both cases it is very restricted.

The rocks of the Peek Hill type are quarried for road metal in the Lostwithiel district, and in the Brent and other Devon localities. The Eifelian mudstones, and the silty and argillaceous rocks in the Lower Devonian which resemble them, are quarried for building purposes, the laminæ or cleavage planes in both types being coherent and joints or planes of schistosity occurring in such a way as to yield large blocks.

CARBONIFEROUS.

The writer was engaged for a fortnight on field work in the Newton Abbot area, where a boundary had not previously been drawn between the Lower Culm Measures and overlying shales and grits. At the same time the conglomeratic greywacke beds of the area were carefully noted with the view of explaining the enigmatical occurrence of the greywacke sandstones of the Plymouth and Saltash area (of Efford and Wearde Quay) to which a similar date of formation has been assigned. To ascertain the very intricate relations of the rocks between Bickington, Ilsington, and Bovey Tracey (mapped without subdivision of the Culm in 1887, on the old one-inch map) it was found absolutely necessary to re-map four square miles on the six-inch scale.

In the Lower Culm succession in the Ashton and Trusham district the *Posidonomya* and *Goniatites spiralis* beds (hard mudstones, shales, and occasional seams or beds of limestone) overlie chert beds succeeded by hard dark mudstones and dark shales. This section, in the road from Farley to Trusham station is the most complete one in the district; the chert beds in it are of no great thickness (perhaps 20 feet) and are separated by volcanic tuffs from the *Posidonomya* bed above.

Skirting the granite to Bovey we encounter in the altered rocks of the Lower Culm many intrusive masses of greenstone, and occasional bands which seem to be contemporaneous felspathic tuffs. These felspathic bands occur near Stickwick and Bovey Tracey. The railway cuttings from Bovey towards Lustleigh display dark shaly rocks which may be included in the Middle Culm. A mass of felsite occurs on the margin of the granite near Woolley. This rock is for the most part coarse, at first sight simulating a Culm conglomerate owing to blebs of quartz, pieces and granules of a black substance, probably schorl rock, and pieces of felspar. Felsite is again seen by the railway where it bends northward to Lustleigh, and near this, towards Hisley, a mass of altered greenstone is in contact with the granite. There are eight patches of greenstone in the doubtful Middle or Lower Culm rocks between this mass and Bovey Tracey. From Yarner Wood southward to Bickington the boundaries between Lower and Middle Culm were traced, although there are numerous faults which bring up inliers of Upper Devonian. The hard shales with *Posidonomya* were identified and also chert beds, which rest on the Upper Devonian near Liverton. Out of ten patches of intrusive greenstone in this district two occur in the Upper Devonian inliers and eight in the Lower Culm. The Ashton and Trusham districts exhibit the same absence of intrusive rocks in the Middle Culm Measures. From Doddiscombleigh on the north to Bickington on the south, this main outcrop of Lower Culm rocks passes under dark slates, with hard beds of greywacke grit and sandstone more or less fine in grain and with no traces of conglomerate.

The Ugbrooke Park greywackes exhibit every variety of grain from a fine dense rock to a conglomerate containing stones from a quarter to half an inch in diameter. In many respects these greywackes are the counterparts of the Wearde-Efford beds, and of the Middle Culm greywackes of the Tavistock district and the St. Mellion outlier in Cornwall. All these, especially the coarser varieties, show derivation from igneous and fine-grained sedimentary rocks. In the coarser beds of Ugbrooke Park, south of Oldchard and Ideford, and in the faulted outliers between Newton Abbot and Ipplepen, the sedimentary fragments include a fair percentage of Lower Culm chert, and of fine-grained dark rocks, no doubt also derived from the Lower Culm. The sedimentary inclusions in the Wearde-Efford greywacke are generally of dark shale, but pieces of (Culm?) chert were obtained in a coarser band near St. Erney, in East Cornwall. The conglomerate beds in all the above districts contain besides

quartz a large percentage of igneous fragments of various kinds, and many of the harder fragments are well worn.

Wherever the Ugbooke Park greywackes are in unfaulted relation with the numerous inliers of Lower Culm they are found to rest on the *Posidonomya* (or *Goniatites spiralis**) beds. The chert beds are not exposed in these inliers although they must be represented in the area, as two small faulted patches have been recognised, one near Chudleigh (north of Lawell House), the other near Bishopsteignton (north of Coombeway).

The greywackes rest in places (as at Gappagh and in the outliers between Newton Abbot and Ipplepen) on dark irregular shales which may (as west of Bovey Tracey) belong either to the Middle or Lower Culm. These broken shales occur at Bishopsteignton, and have been mapped as Culm measures. The Efford greywackes near Plymouth rest on similar shales. In the Tavistock volcanic district the same difficulty as regards the occurence of dark shales of doubtful character exists.

At Beer Alston Station an outlier of greywacke rests on some beds of grey chert, whilst elsewhere nothing intervenes between its base and the Upper Devonian. In the St. Mellion outlier the *Posidonomya* beds, chert beds, and dark mudstones and shales are represented, apparently in normal sequence, below the Middle Culm greywacke. There is a small outlier of black Culm chert on Upper Devonian slates near Tamerton Folliott. At Wearde, south of Saltash, the greywacke rests on dark slates or shales, on Dolerite, and on volcanic rocks. As far west as Padderda, near Menheniot, traces of greywacke are met with, often accompanied by the equivocal dark slates or shales, and always amongst volcanic rocks, and Upper Devonian slates. In these cases no boundary can be satisfactory drawn to separate the Middle Culm greywacke from the Upper Devonian. For two years after their discovery in 1893 and 1894, the writer regarded the Wearde-Efford greywackes as contemporaneous with the volcanic rocks in the Upper Devonian. Subsequent field work in the Culm Measures of the Tavistock and St. Mellion district corroborated by the petrological examination of the rocks by Professor Watts, (which showed that whilst none of the specimens gave conclusive evidence of contemporaneous volcanic activity "angular fragments of many rocks such as felsite, andesite and micropegmatite," and quartz grains often strained, suggested the denudation of a volcanic series, and of gneissose or schistose rocks), and by the discovery of chert in the greywacke at St. Erney, led him to correlate them with the Middle Culm.

The collective evidence, which must remain incomplete until the area west of Dartmoor is re-surveyed, suggests some such explanation as the following. During the final stages in the deposition of the Upper Devonian vulcanicity from local centres prevailed, in places continuing during the formation of the Lower Culm rocks. The elevation that succeeded the deposition

* In Dr. Woodward's list of fossils from these beds near Waddon Barton, *Goniatites spiralis*, the most abundant form there, is omitted.

of the Lower Culm, although universal, was not uniform. Over a large part of the area the later stages of this movement were so gradual and uniform that the *Posidonomya* shales and limestones seem to pass up into the plant-bearing grits and shales. The section at Perridge Tunnel on the new line from Ashton to Exeter, and some of the Bampton quarries bear out this view.

Over those parts of the area where the crust had recently been weakened by volcanic activity and igneous intrusions, irregularities in elevation would have led to the destruction and dispersal over the shallow sea-bed of such Volcanic and Lower Culm rocks as had thus been exposed to denudation. The occurence of the Wearde-Efford greywacke, and the local irregularities in junction between Middle and Lower Culm of which the Bere Alston outlier is an example, point to this conclusion.

The faults and plications in the Lower Culm render it impossible to form any absolute estimate of their thickness. There is no doubt that their constituent hard shales and limestones, cherts, and shales form horizons which exhibit a reciprocal thinning and thickening—and there are indications of the prevalence of the dark shale and mudstone type in volcanic areas. A thickness of 300 feet, may be considered too liberal an estimate for their maximum development.

IV. The Coal Measures of Llanelly, Llannon, and Cross Hands in the South Wales Coal Field.

By A. STRAHAN, M.A., T. C. CANTRILL, B.Sc. and E. E. L. DIXON, B.Sc.

Mr. Strahan. The past year's work in the Coal Measures has been carried on in the North Crop near Cross Hands and Pontyberem by Mr. Cantrill, in the Pennant region near Llannon by Mr. Dixon, and on the south side of the Coal Field around Llangennech, Llanelly, and Pembrey by Mr. Strahan.

SOUTHERN REGION.

The South Crop lies under Carmarthen Bay, and the main synclinal axes of the Coal Field pass, the one under Llanelly and the foreshore near Pwll and Pembrey, the other under the sea, where its position remains to be proved. The Llanelly syncline, in conjuction with a series of faults all throwing down to the east, introduces the highest measures existent in the Coal Field. The highest known coal is believed to be one found near Gelli House some distance above the Gelli Vein, but possibly still higher measures are thrown in by the Plas-isaf Fault under part of the Loughor Valley.

In the Summary of Progress for 1901 allusion was made to the difficulty of identifying the Grovesend Veins. Though some uncertainty still exists as to their exact position in the series, much light has been thrown on the question by information supplied by Messrs. Thomas Williams & Sons, and by Mr. John Roberts. In the first place it seems to have been proved beyond doubt that

the fault by which these veins were thrown down against the Swansea Four-feet Vein in the Mountain Colliery was of great magnitude. It not only had that appearance, but a bore-hole put down near the mouth of the Mountain Drift failed to prove the Four-feet Vein within 200 yards of the surface. The sinking of the Cefn-arda Shaft has confirmed the fact that a great thickness of barren measures underlies the Grovesend Veins. Starting about sixty yards below the Lower Vein of the Grovesend group this shaft proved no coal worthy of mention until it reached a depth of 255 yards, when the following seam was traversed:—

Supposed Four-feet Vein, Cefn-arda.

	ft.	in.
Clift		
Coal	2	0
Stone	1	0
Coal	1	0

The identification of this seam as the Swansea Four-feet involves its correlation with the Big Vein or Six-feet of Llanelly. Unlike as the two seams are, the correlation is not improbable. The Four-feet, as proved in the region of Gorseinon and Pontardulais, is far inferior to the same seam as proved in the South Crop and near Llanelly, while still further north it appears to share the fate of the Five-feet, Hughes Veins and others, and to pass into a mere smut. A shaft at Pontardulais, two and a half miles north of Cefn-arda, proves the Four-feet Vein as follow:—

West Merthyr Pit, Pontardulais.

	ft.	in.
Shale		
Coal	1	10
Rashes	0	8
Coal	0	8
[Rashes]	1	3
Coal	1	0

Against the identification of the Cefn-arda Seam as the Four-feet, it may be urged that the seams which usually lie above the Four-feet have not been detected. At Pontardulais, in the West Merthyr Pit, a coal, 1 foot 1 in. thick, and corresponding possibly to the Loughor Little Vein, lies 18 yards above the Four-feet. Above this again is the Pen-ys-callen Vein which is believed to crop 300 yards south of the shaft, and the Stinking Vein which is being worked by slant 600 yards south of the shaft. Turning to the neighbourhood of Loughor we find that the Pen-ys-callen Vein has been much worked and that the Stinking Vein has been proved 30 yards above it, while the Broadoak Shaft shows that the Pen-ys-callen and Loughor Little Veins lie 63 and 43 yards respectively above the Swansea Four-feet Vein. Again in a westerly direction the shaft of St. David's Colliery shows a seam 57 yards above the Swansea Four-feet, another 69 yards above that coal, and the Gelli Vein 189 yards above that coal. The Cae Colliery shaft passed through the Clement's Vein 44 yards above the Swansea Four-feet, a seam 2 feet thick 42 yards above the Four-feet, and another 19 yards above that vein.

Of the veins here mentioned, none quite correspond in posi to the Grovesend group on the supposition that the seam pro at Cefn-arda is the Four-feet. The Gelli Vein comes nea but whereas the Grovesend Lower Vein appears to be more t 300 yards above the vein in Cefn-arda shaft, the Gelli Vein less than 200 yards above the Four-feet (or Box Big Vein St. David's. To this must be added the fact that no equiva of the Stinking, Pen-ys-callen or Loughor Little Vein has b recognised at Cefn-arda.

So far the identification of the Cefn-arda Seam as the Swa Four-feet appears to be contrary to evidence. It is diffic however, to see what other correlation is more probable, for t is no such mass of barren measures known in the neighbourh as has been proved in the Cefn-arda Shaft. If the seam re sents the Swansea Five-feet, the absence of the Swansea F feet remains unexplained; if it represents the Swansea Six-f the absence of both the Four-feet and Five-feet has to accounted for.

An objection to the correlation of the Cefn-arda seam with Four-feet, which was mentioned in the *Summary of Progress 1901*, p. 45, lay in the fact that it implied a throw of not than 200 yards in the fault proved in the Mountain sh although no fault of such magnitude had been recognised eit to the north or south of the spot. That none can be tra more than a mile to the south is true, but the past year's w has shown reason to believe that the Mountain Fault only continues northwards, but that it forms one of a serie great easterly downthrows. The evidence lies in the position the group of seams known as the Fiery (Swansea Six-feet), Golden (Swansea Three-feet), and the Bushy (Swansea Two-f to the west of Pontardulais.

The Graigola or Six-feet Seam can be traced continuously al the north-west side of Cefn Drum as far as the fault which r from Gorseinon by Bolgoed, and thence probably to G Wallis. This fault, being a downthrow west, must throw crop of the Six-feet northwards, and accordingly at Tal-y-fan find a seam in about the expected position. The coal worked in 1877 and proved to be 3 feet 9 inches thick and sc therein differing from the Six-feet Vein of Birch Rock which alw contains a parting. It was believed, however, to be that v and a trial-pit in a field close by proved a seam 22 inches th at a depth of 22 yards, which was thought to be the Swansea T feet. The workings encountered faults in every direction were abandoned without anything definite having been pro but the evidence as to the position of the Four-feet, afforded the West Merthyr Pit previously mentioned, goes far to pr that the Tal-y-fan Vein must be either the Six-feet, or one the group to which that vein belongs. If it is the Six- the absence of any known outcrop for the Five-feet V may be attributed to the highly disturbed state of ground.

Crossing now to the west side of the Loughor we find a vein being worked at Fforest and cropping close to Pontardulais Bridge. The coal is 2 feet 9 inches thick and is considered to be the Swansea Five-feet Seam. To the south of and above it there crops out a massive sandstone which is quarried at Hendy, but all overlying rocks are concealed by gravel and alluvium. To the north there rise from beneath it the sandstones and shales of Fforest, and at their base a group of three seams which have been worked round the north slope of the hill. These may be taken to represent the Six-feet, Three-feet, and Two-feet, and to confirm the identification of the Fforest seam as the Five-feet, the Four-feet presumably cropping under the gravel near Hendy. If now we consider the relative levels of these veins with those of Pontardulais we find that a large easterly downthrow must intervene. The Swansea Five-feet of Fforest, for example, is approximately on a level with the Pen-ys-callen of Pontardulais, from which the throw of the fault may be inferred to be about 200 yards. By some authorities the Fforest seam is thought to be the Swansea Four-feet, in which case the throw of this fault would be about 100 yards less, but another, presently to be mentioned, correspondingly increased.

The fault thus inferred may be supposed to run near Pontardulais Bridge and along the Loughor towards Llanedy. It helps to account for the form of the valley, which is unusual in respect of the facts that it is broad, and that it is divided into two branches by the rock-hills of Tal-y-fan and Tyn-y-bonau. The Loughor runs now on the west side of these hills, but there is an almost equally deep and broader depression on the east side. The two depressions correspond locally to, and no doubt have been determined by, the two faults described above. Southwards the fault ranges for Waun-gron, where there is evidence of disturbed ground, though it has not been reached in the workings of the Grovesend Seams. The line continued in the same direction leads to the point where the Mountain slant passed from the Grovesend Lower Seam into the Four-feet. Still further south it may be identified in an easterly downthrow proved in the old workings under Loughor Common, the position of which is recorded by a stone marked "falt," while further on again it appears to be the fault which limits the workings in the Five-feet from Cae Duke This is the last known of it, unless it can be proved to cross the alluvial tract to Gurnos where is an easterly downthrow in the Three-feet and Two-feet veins.

The second of the series of easterly downthrows runs along the Gwili valley. On the west side of that valley the Golden Vein (Swansea Three-feet) is being worked for clay at the Tal-y-clyn Brickworks, while the Fiery (Swansea Six-feet) and the Swansea Five-feet have been proved in their proper relative positions. The Swansea Five-feet was worked by a slant 350 yards south of Tal-y-clyn-uchaf, on the west side of the fault, and by a level at Felin Fforest, nearly a mile further north, on the east side of the fault. Assuming the dip to average 6 inches to the yard, this displacement of outcrop implies a vertical throw of about 290

yards, or if the Fforest seam be the Four-feet, the throw would be about 390 yards. The fault is believed to run close to Tal-y-clyn-uchaf, passing thence under the alluvium and across the higher ground about 200 yards west of Pen-yr-heol. Eighty yards west of that house a fault was touched in the Mountain workings, but the form of the ground suggests that the main fracture may lie a little further west as stated. Continued southwards the line falls nearly into that of the Pengrys Fault, which, however, is a downthrow west.

The third of the series of easterly downthrows has been proved at the Morlais Colliery to have a shift of 45 yards. It runs under a ravine 400 yards north-east of Tal-y-clyn-isaf and thence under Pen-lan. Southwards it passes into unproved ground under the alluvium and gravel of the Loughor.

The fourth of the series is known as the *Plas-isaf Fault*. It has not been actually proved under the Loughor at Loughor, but its effects were seen in the easternmost workings of the Golden and Fiery Veins from Bynea. The level course turned abruptly from E. 18° S. to north and south, at a point nearly north of the Yspytty Works, and the veins assumed an easterly dip. Disturbed ground was reached from Broadoak also in the Swansea Four-feet Seam, nearly under the centre of the tidal area. The displacement was estimated at 200 yards. Northwards the line of fault is more clearly defined; it runs almost exactly under the Llanelly and Llangennech Railway past Plas-isaf Colliery, a slant 500 yards south of that colliery having started in it. At Llangennech a trial-pit proved what is supposed to have been the Gelli Vein on the east side, while the Box Big Vein (Swansea Four-feet) crops closely on the west side, the throw here being a little less than 200 yards. The fault is well exposed in the Morlais 400 yards north of Llangennech Mill, and runs along the east side of the Morlais Valley, cutting off the crops of the Swansea Five-Feet at Tir Eglwys and those of the Fiery, Golden, and Bushy in succession. The displacement of outcrop of the Big Vein amounts to 1,400 yards. The Plas-isaf Fault is not known in Gower, the only fault which lies in its range being a downthrow west.

The fifth of the series of easterly downthrows is known as the *Bryn-serfyll Fault*, and has been proved in all the seams from the Llandilo branch of the Great Western Railway as far north as Clyn-gwernen, where it cuts the outcrop of the Llanelly Four-feet (Five-feet) Vein. Farther north it can be traced for some three miles by surface-evidence, passing about 300 yards west of Clochyrie. Near Dafen its throw appears to be about 245 yards from the fact that the Gelli Vein was reached at 56 yards depth in the Gelli Pit on the east side, while the Box Big Vein crops out close by on the west side. The distance between these two veins is 189 yards as proved at St. Davids.

The sixth easterly downthrow is known as the *Box Fault or Box Great Bar*, a small fault about 150 to 250 yards west of it being known as the Little Bar. The Box Fault may be seen cutting through the Pennant rock of the Pen-y-fan quarries, and

has been proved thence northwards in the principal veins as far as Box Cemetery. There an old level, said to have been the Rosy Vein, is nearly opposite old crop-workings in the Box Big Vein, which would imply a displacement of about 150 yards, but the crops of the Fiery, Golden and Bushy indicate a considerably smaller shift. The fault, however, can be traced for more than a mile north of Felin-foel by its effect upon the succession of outcrops of small veins below the Bushy. The line thus evidenced runs about 100 yards west of Llwyn-y-piod.

The seventh easterly downthrow is known as the *Stradey Fault*. It was worked up to in the Golden Vein and others from the Old Castle Pit and proved to run at the foot of the steep Pennant hill of Stradey Wood, through Cwm-bach. Inasmuch as it threw out all the seams down to the Bushy, the determination of its throw depended on the identification of a vein worked on its west side at Pwll with one of those which underlie the Bushy at Cille, a matter which is discussed later on. It was estimated that the throw could not be less than 200 yards, and was probably as much as 280 or 290 yards. Two other faults were proved in the Old Castle workings, and were known respectively as the Nine-fathom and Twenty-eight-fathom Faults. Both were downthrows to the west.

The eighth easterly downthrow cuts off the Pwll workings and crosses the hill 200 yards east of Moreb to Gwr-aeth. The throw is small as compared with those previously described. Others have been proved at Burry Port and west of Pembrey but none were of the first magnitude.

The faults enumerated above all belong to the N.N.W. system which is so conspicuous throughout the South Wales Coal Field. Their age has been discussed and the conclusion formed that though they break through the Trias and Lias, they were partly also of earlier date, inasmuch as their effects are greater in the Carboniferous than in the Secondary Rocks. However, this may be, the fact that they cut right across the structures due to the pre-Triassic folding of Gower and Carmarthenshire is obvious, and is unusually well illustrated in the area surveyed during the past year.

The town of Llanelly stands in the centre of a deep syncline which has been traced continuously from the Loughor to Burry Port. The fold may perhaps be regarded as commencing between the Lliw and the Loughor, where a syncline was proved in old workings in the Four-feet Vein under Loughor Common. The synclinal axis trended nearly N.W. in the direction of Ty-coch on the west of the Loughor, where the Llanelly syncline is well developed.

At Ty-coch it is possible to see in the low cliff much of the structure which characterises the syncline in its course through the Pencoed, Cae and Old Castle collieries. On its south side the dip is always steeper than in the north, and in places reaches an angle of 45°. In the immediate neighbourhood of the bottom of the trough in the Pencoed Colliery the dip increases almost to verticality, and the veins have proved unworkable for

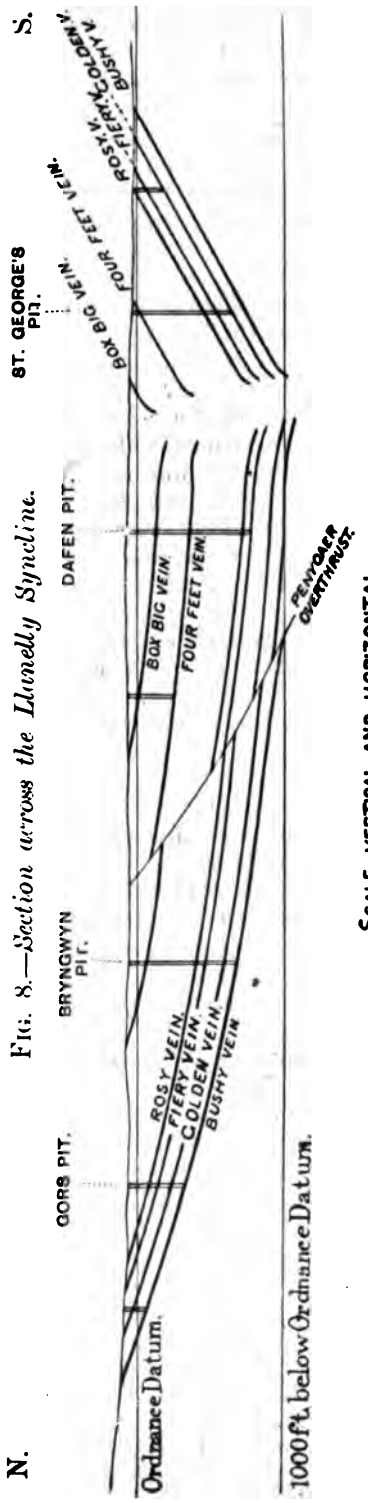

Fig. 8.—*Section across the Llanelly Syncline.*

a breadth of some three or four chains; to the north of the trough the veins come again into their proper positions and rise gently up to their north crop. The axial plane of the syncline thus proved in the successive seams is inclined to the south at a high angle, so that its position at the surface lies considerably to the north of its position in the Fiery group of veins. Another interesting feature in the structure which was proved at Dafen, and is known as the Pen-y-gaer Fault, consists in an overthrust ranging east and west and cutting the veins as they rise northwards from the trough. It hades south at an angle of about 30° from the horizontal, and causes an "overlap" of about 20 or 30 yards in the veins. The section forming Fig. 8, which is reduced with slight modification from a plan in the possession of Messrs. Nevill, Druce and Co., gives a vivid representation of these structures, and of the effect of the wave of compression from the south to which they were due

The description given above applies to the region west of the Box Fault, except that at the Old Castle and Pwll Collieries the synclinal axis was not broken, and there was no overthrust corresponding to the "Pen-y-gaer Fault." The dip however averaged 14½ inches to the yard on the south side of the trough, as compared with 6 inches to the yard on the north side.

The axis of the syncline runs under low ground generally and under a broad foreshore from Llanelly westwards Northwards from it

the Pennant rocks rise into characteristic hills, but there is no corresponding outcrop on its south side. The explanation is found in what is known as the "anticline," which, however, may be more correctly described as a series of step faults accompanied by a flattening of the measures. The existence of the structure is of the greatest importance with respect to the quantity of coal existing under the foreshore and estuary, but has been proved for a short distance only. No clue whatever to its existence is visible on the surface.

The "anticline" was proved in the Carnarfon Pit near Dyffryn. To the north of the colliery the Rosy, Fiery, Golden and Bushy Veins crop in their proper places on the south side of the syncline, the Bushy coming near the surface close to the pits. The more northern of the two pits however, was sunk on a fault with a downthrow south, and in working the coal north of Dyffryn Crossing, this disturbance was found to consist of a series of step-faults all downthrows south, as many as five having been proved before it became impracticable to follow them down any further. The net result is to throw the Rosy, Fiery, Golden, and Bushy Veins in again; the Rosy was proved at 48 yards depth in the southern Carnarfon Pit, and the Fiery at 24 yards depth in an air-pit 50 yards north of Dyffryn Crossing. The Golden was proved at 38 yards depth in a pit on the south side of the railway 580 yards further west, and at 34 yards depth in a pit 200 yards west-north-west of Bryn Carnarfon. The Bushy was proved at 70 yards depth in the Caedu Pit 150 yards east of Bryn Carnarfon, and at 42 yards in the Tir-bacas Pit. The aggregate throw of the step-faults may be estimated by comparing the positions of the Rosy and Bushy Veins at Carnarfon; the former in the south pit is about 43 yards below the position of the Bushy on the north side of the "anticline." The Rosy should be about 88 yards above the Bushy, from which it would appear that it is thrown down 131 yards; but the estimate is not wholly reliable, for there are said to be other faults, one for example under the Great Western Railway.

The Bushy Vein was followed southwards from the Tir-bacas pit for a distance of 7 chains with a rise of 1 in 3½, when it was thrown out by a fault, parallel to the "anticline," but with an upthrow south. The throw of the fault was not ascertained inasmuch as it threw the Bushy Vein out, and the ground south of it remains unknown.

Returning now to the "anticline" we get proof of its approximate course westwards near Llandilo Crossing, where Evans Pit proved the Bushy at 40 yards depth. As that vein crops in the south side of the syncline some 600 yards farther north, there is evidently a large downthrow south between that crop and the pit.

The line thus indicated prolonged for a mile westwards brings us to the Pen-y-fan quarries. The rock there worked is a massive sandstone lying some distance below the Bushy Vein. It dips north, but at about 13° only as compared with the dip of about 29° which prevails at St. George's. To this fact, whic[redacted]

in itself suggests the neighbourhood of the "anticline," may be added the existence of a small east and west fault with a down-throw south. The fault follows the foot of the sandstone-scarp, and is likely to be the first of a series of steps such as those which constitute the "anticline" farther east. The direction of the anticline at Pen-y-fan, as suggested by the form of the ground, appears to be due east and west, while its general course thence to Carnarfon Pit is about E. 14° S., but it must be remembered that it is crossed by the Box and Bryn-serfyll faults and probably shifted by both. Westwards from Pen-y-fan it appears to range for the new dock at Llanelly, but though the rock was exposed in the dock-bottom the existence of the "anticline" was not determined, for the dip was northward at a high angle. It may be mentioned, however, that a coal-crop was disclosed, about the identity of which there is some doubt. It is commonly supposed to have been the Bushy Vein, but it occurred near the south end of the dock at a distance of 750 yards south of the Old Castle Pit. The Bushy Vein was 185 yards down in that pit and is shown on the plans as cropping about 500 yards south of the pit, with a rise of 22° (14½ inches to the yard). Moreover, the seam exposed in the dock was double, and consisted of an upper coal, 2 feet 6 inches thick, and a lower coal, 1 foot 4 inches, with clay between, whereas the Bushy Vein is said to have been a solid coal, 2 feet 10 inches thick.

Two trials on the south side of the "anticline" have still to be mentioned. One known as the Great Morfa colliery is situated on the sea-bank 600 yards north of Penrhyn-gwyn. The following section of the pit and borehole is condensed from an account supplied by Mr. W. Watkeys:—

Great Morfa Colliery.

	ft.	in.
Filling up to level of bank	8	0
Soft clay with two beds of peat, the lower 30 feet below the top of the pit	32	6
Quicksand	2	0
Gravel	22	0
Measures	32	10
Coal No. 1 (a good bituminous coal; further east 3 ft. thick)	2	6
Measures	139	8
Coal No. 2 (further east 2 ft. thick)	1	6
Measures	174	1
Coal	1	1
Measures	12	2
Coal	0	8
Measures	38	6
Coal	0	7
Measures	1	9
Coal	1	0
Measures	57	4
Coal	1	6
Measures	6	9

The dip was 1 in 9 in a direction S. 11° W. None of the coals proved were identified.

The second trial referred to was near Tir-morfa-fawr. Two shafts were sunk and a coal 1 feet 6 inches to 2 feet 3 inches in thickness was proved at a depth of 70 yards, which was thought to be Cille No. 2 Seam. The dip was gentle in a direction slightly west of south. The southerly dip seen in both the Great Morfa and Tir-morfa pits proves that the bottom of the syncline which runs between Gowerton and Loughor must be still further south, and the true South Crop of the Coal Field further south again. As a matter of fact a line of level course through the Morfa Colliery runs parallel to and only 1 mile 270 yards north of a line of level course in the Penclawdd Vein at the Penlan Colliery in the South Crop in Gower. The Penclawdd Vein runs through Gower at a distance of nearly 1¾ miles south of the Gowerton syncline. It seems probable therefore that the South Crop and the syncline must get narrower westwards. The effect is such as might be produced by the syncline becoming shallower in that direction, as indeed is known to be the case in the Llanelly syncline.

The Stradey Fault throws out the Bushy Vein, the lowest of the group which has yielded the bulk of the coal near Llanelly and Swansea. West of it several coals have been worked in the Pennant, and among them should be found the representative of the Hughes Vein. The succession can be determined by crossing the outcrops either northwards on the east side of the Stradey Fault or westward where they come down in succession to the coast-line west of that fault. North of Llanelly they have been worked by a level at the Cille Colliery. Four seams, known as the Cille Nos. 1, 2, 3, and 4, were proved and No 2 has been worked. At the mouth of the level a borehole was put down through and below the same measures. It started about 70 feet below the Bushy Vein and proved the following seams:—

	ft.	in.		ft.	
Cille No. 1 Seam - - - -		10½	thick at	166	depth.
Cille No. 2 Seam - - - -	1	11	„	202	„
Cille No. 3 Seam - - - -	1	6	„	272	„
Cille No. 4 Seam - - - -	1	7	„	333	„
Coal - - - - - -		5	„	557	„
Coal - - - - - -	2	2	„	655	„
Coal - - - - - -	1	0	„	659	„
Cille No. 5 Seam - - - -	2	4	„	664	„
Cille No. 6 Seam - - -	1	3	„	887	„

Of these, No. 2 crops out by the side of the road to Five Roads; No. 4 crops out at Cilau-gwyn; No. 5 crops out near Pant-y-llydu-fach; while No. 6 may be a coal which has been worked at Trefanau and is said to be 3 or 4 feet thick. As far as Trefanau and for 800 yards north of it the sequence continues unbroken, but the dip steadily increases up to nearly 50°. The beds then turn over and dip gently to the north, with signs of overthrusting. What appears to be the crest of the anticline and principal overthrust is still under investigation, but it may

be mentioned now that a quarry in a dingle on the west side of the Mynydd-mawr Railway, 600 yards south of Horeb, gives a remarkable view of a part of the structure. The quarry has been opened through some few feet of completely ground-up rock into a hard thin-bedded sandstone below. The plane between the two is clean-cut and slants down southwards at 16°; the rock beneath it dips north at 12°, but in places, just below the plane, the edges of the beds have been doubled back. It is to be noted that this overthrust ranges east and west and "dips" south as does the "Pen-y-gaer Fault," that the burring of the edges of the beds shews the overthrusting to have taken place from the south, and lastly that the rocks above the plane are disintegrated, while those below are sound and hard.

We have now to pick up the equivalent of the Cille veins on the west side of the Stradey Fault. Working northwards, as before, we pass the following outcrops. The Pwll Vein and the Little Pwll Vein, 35 yards above it, crop at the Stradey Stables, through Stradey Wood, and reach the edge of the marsh some 300 yards west of Pwll Colliery. The Pwll Vein was reached at 50 yards depth in the shaft of that colliery and was worked under the foreshore for about 800 yards south of the Great Western Railway, the coal being followed continuously down to the bottom of the Llanelly syncline and up the rise to the south of it.

The next seam in descending order has been worked near Cil-y-maenllwyd and is known by that name or as the Weasel or Shenkin Vein. It is said to be 18 inches thick, but appears to be quite local. A more constant seam is now being got at the Cwm-mawr Colliery and has been worked south-east of Gwr-aeth. It is said to be 22 inches thick. The Cwm-mawr Vein is thought to be the Pant-y-llydu-fach or Cille No. 5 Vein of the east side of the Stradey Fault.

Another clue to the identification has been found in the Pwll Veins. The vein proved in the Cille Borehole at a depth of 557 feet, and the ground immediately above and beneath it, is supposed to be identical with the Little Vein now worked at Pwll Level. If this be so, the vein, 2 feet 2 inches thick, proved in the borehole at 655 feet depth, will correspond to the Pwll Vein, but on this supposition Cille No. 5 is too close under the supposed Pwll Vein for the Cwm-mawr Vein. Further discussion, however, on the correlation is reserved until the ground west of the Stradey Fault has been examined.

The workings in the Pwll and Cwm-mawr Vein are limited on the west by a downthrow east which passes 200 yards east of Moreb. The effect is to throw the outcrop of the Cwm-mawr Seam under the foreshore, where its position has not been determined, while the next seam below, known as the Clay Seam, is thrown nearly into the position that would have been occupied by the Cwm-mawr Vein in the absence of the fault. The Clay Vein is about 1 foot 6 inches thick and is worked for its under-

clay for the manufacture of firebricks. Its crop runs by Lletty'r-ychen-fawr and Plas-newydd. Four hundred and fifty yards to the north of it we reach a well-marked group of coals with soft measures, the outcrop of which is marked by the deep strike-ravine of Cwm Ierman. Four coals occur, namely, the Gyscwm Rider, the Gyscwm, the Rhengog-fach and the Rhengog-fawr.

Below the Rhengog-fawr there comes an extremely massive rock, about 500 feet thick, below which lies the Cenrhos Vein, 4 feet thick. The Gyscwm Vein crops close to Achddu Mill and passes thence under the gravel to near Furnace, whence it strikes across the hills by Pen-llwyn-isaf, its position marked everywhere by a depression dominated on the north by the outcrop of the Cenrhos Rock. The Cenrhos Vein on the other hand crops in the high plateau, there being comparatively little soft ground associated with it.

It will be noticed that there are two breaks in the continuity of the sequence, both due to faults, namely at Stradey and Moreb. In both cases an examination of the country further north is likely to furnish the evidence necessary to complete the sequence, but at present we have not the data for estimating the distance between the Cwm-mawr and Gyscwm Veins, further than that the former is said to crop near the mouth of the New Lodge Level, while the latter is reached in the level 670 yards from the mouth. With a dip of 1 in 3 this indicates a distance of about 215 yards between the two veins, vertically to the bedding. In the same level the Clay Vein was reached at 300 yards from the mouth, or about 95 yards below the supposed position of the Cwm-mawr Vein.

From the Clay Vein downwards the sequence has been proved in various levels and shafts. The detailed measurements were incorporated by Sir W. Logan in Sheet 1 of the Vertical Sections of the Geological Survey, from which the following abstract is taken:—

	ft.	in.
Sandstone with some beds of shale	200	0
Clay or Gwdig Vein	1	2
Shale with a few thin bands of coal	70	0
Sandstone with some beds of shale	255	0
[Gyscwm Rider] impersistent		
Shale [expanding rapidly from east to west]	27	0
Gyscwm Vein	3	0
Shales with some sandstone	75	0
Thin coal		
Shale	8	0
Rhengog-fach Seam	1	2
Shale	77	0
Rhengog-fawr Seam with partings	4	0
Underclay	2	6
Coal	1	0
Underclay	5	0
Sandstone	500	0
Cenrhos Seam	4	0

In 1864 an unsuccessful attempt was made to reach the Gyscwm Vein at Elliott's Metal Company's Works, Burry Port, and the following section was proved:—

Burry Port Trial Pit.

	ft.	in.
Sand [Blown sand]	28	6
Clay	4	6
Gravel [Glacial ?]	25	0
Sandstone with shale	214	11
Coal	0	3
Shale	26	6
Coal	0	5
Shale and clay	64	0
Coal, supposed Clay or Gwdig Vein	2	0
Clay	1	6
Sandstone	89	0

The measures dipped northwards at 2 inches to the yard, the pit being situated on the south side of the syncline which underlies Llanelly and Pwll.

In Stanley's Pit (the New Pit of the Six-inch Ordnance Map), the vein was reached and worked under the foreshore down to the bottom of that syncline. The shaft traversed the following section:—

Stanley's Pit, Pembrey.

	ft.	in.
Superficial deposits [Glacial]	120	0
Sandstone	144	0
Shale	12	0
Coal	1	0
Shale, etc.	1	6
Coal	1	0
Clay, etc.	6	0
Sandstone	42	0
Gyscwm Seam	3	6

It will be noticed that the shale which overlies the Gyscwm Seam in Cwm Iorman, and which expands westwards, is replaced here by sandstone, if the description is correct.

A seam supposed to be the Gyscwm is now worked at Craiglon, the section being:—

	ft.	in.
Clift		
Rashings	0	6
Coal, in places 3 ft. 6 in., but generally	2	6

The level course runs nearly due east and west, so that the crop, if not faulted, will pass under the blown sand and marsh. That tract has not yet been proved.

Turning now to the region lying north of Llanelly we are met with the fact that of the eight easterly downthrows enumerated above, the majority fail to extend so far north as Llannon. On the contrary, nearly all the faults of the N.N.W. system, of which evidence has been obtained in that neighbourhood and north of it, are downthrows to the west.

Mr. Strahan, Mr. Cantrill, and Mr. Dixon.

The Bettws Fault was found by Mr. Cantrill to be obvious in the Red Vein, south of Bettws, and again in the Millstone Grit west of Llandybie. The downthrow is westward, but of unknown amount.

A downthrow east of 17 yards is said to run under the alluvium between the old Pont-y-clerc colliery and the brick-works. A westerly downthrow was touched at Fairwater from Pant-y-ffynnon old colliery. Mr. Strahan, Mr. Cantrill and Mr. Dixon.

The Hendre Fault, which runs from the alluvium of the Loughor at Erw-wastad-fach, is a downthrow west, and displaces the crop of the cockshot band at Clawdd-du. Its effects at Hendre will be mentioned on p. 185; northwards, it decreases in throw, and appears to be only 21 yards in the Emlyn workings.

The fault mentioned in the *Summary of Progress* for 1900 (p. 98), as having been proved from Gorseinon and Carn-goch to be a downthrow west of 67 yards, ranges by Bolgoed and the Fountain Inn to near Tal-y-fan. West of the Loughor it passes up Glyn Wallis, and is estimated by Mr. Dixon to have a downthrow west of 200 yards near Pentre-hardd, on the assumption that the coals cropping out at that place are the same as those cropping out at the dingle west of Bryn-bargod. Further north Mr. Cantrill finds it throwing the cockshot at Cefn-gwili. The next fault, which we may name after Bryn-gwili, near Cross Hands, is not known east of the Gwili, but produces a westerly downthrow near Dingle. Its course along the road from Pontardulais to Cross Hands, and its apparently great displacement of the cockshot, will be discussed in connection with the outcrop of that rock. At Cross Hands its effect on the form of the ground, where it separates the soft measures associated with the Big and other veins from the sandstone-ground on its west, makes a part of its course sufficiently obvious, but further north it becomes obscure. It is probably the fault which shifts the Millstone Grit at Craig-y-geifr, and greatly displaces the Limestone at Trawsdre-ganol. Soon after it joins an easterly downthrow, by which it is apparently neutralised.

The Plas-isaf Fault has not proved traceable north of Goitre-wen, but a little to the east of it a fault commences which is exposed in a dingle south of Pant-yr-yn, with a hade to the east. It apparently crosses the Llannon disturbance, described on p. 184, and shifts the successive outcrops as far as Tumble, always with a downthrow east. It may be the fault which neutralises the Bryn-gwili Fault at Trawsdre-ganol.

A fault which passes Gelli-gwernen appears to range for that which throws the Llanelly Four-feet down west at Corn-hwrdd. It is exposed in the left bank of the Morlais near Coed-cyw Mill, where it cuts through some flexures connected with the Llannon disturbance in a manner to suggest that it is of later date. Further north it throws down west a small seam south-west of Pen-y-cwm-uchaf which serves as the base of the Pennant. It cuts through the cockshot at Pen-llwyn-gwyddau, and appears to fall into line with a westerly downthrow, which shifts the Lower Pumpquart Vein of Clôs-isaf and the Carboniferous Limestone at Garn.

The Bryn-serfyll Fault is believed to run along a broad water-logged hollow through the Cockpithall fold, as though it were of later age than the fold, and than the Llannon disturbance, of which the fold forms part

Mr. Dixon. In the ground surveyed by Mr. Dixon around Llanedy and Llannon, though there are many local exceptions to the rule, the dip of the strata ranges from S.E. to S.S.E. at an average angle of 15°. Over a considerable tract, however, near Llanedy it is south-west, and there is reason to think that the change is due to a break running east and west almost along a dingle near Gwal-yr-hwch. In the west side of the Gwili Valley and in a line with this dingle there is a hollow from which much water issues, and here also we find an analogous local change of dip. No further evidence, however, of a break has been obtained further west. About two miles further on in that direction the south-westerly curves round to the normal south-easterly dip.

What appears to be a line of overthrust runs south-westwards, close by the east side of Llannon. It gives out much water and the ground east of it is wet and low as compared with that to the west of it. The line thus indicated does not follow the strike, and whereas the strata on its eastern side, as seen in the Morlais, are nearly horizontal, those on its western side undulate sharply. South-west of the Morlais the probable position of the disturbance is suggested by a swampy valley which commences at Nant-garedig. Here the strata on its south-eastern side roll over towards the disturbance, and are even inverted.

Close by and to the west of Nant-garedig, another valley carries us along what seems to be the same line of disturbance, and in about 500 yards we get evidence of overthrusting in the outcrop of a seam worked at Maes-llydan. The seam, as shown by old workings, crops much above the stream on the south-east bank, but appears to lie some depth below it in the north-west bank, the relative positions indicating that the fault must hade to the south-east though its downthrow is north-west.

Here the evidence ceases along the direct line, but a row of springs and an abrupt change of ground suggests that the disturbance continues along a line lying about 150 yards further south. The ground to the north-west of this line of disturbance, including Mynydd Sylen and the neighbourhoods of Cynheidre and Brondini, is characterised by a low dip.

NORTH CROP.

Mr. Cantrill. The superficial deposits which occupy the Loughor Valley at Ammanford, together with the Bettws Fault, constitute a barrier between the measures on the east and those on the west; new names are adopted for the seams, and at present little has been attempted towards their correlation. The Red Vein, moreover, is unknown west of the Bettws Fault, and is no longer available as a datum-line.

On the west side of the Loughor and as far as Cross Hands the lower measures, which consist chiefly of shales, are thrown into a series of anticlines and synclines having a general direction varying from E.N.E. and W.S.W. to N.E. and S.W. Some of these rolls have a breadth of nearly a mile, but they are generally still farther complicated by sharp folds of only

a few yards in width. The general nature of the ground is expressed on the old map [41 S.E.], on which the coal-crops were laid down from sources of information no longer available. The anticlines often show dips steeper in the north-west than in the south-east limb. In some cases the folds have passed into thrusts or "overlap-faults" of considerable magnitude; these may be either clean-cut fractures, or narrow belts of highly disturbed ground; but in both cases the thrust makes usually a small angle with the vertical, and the beds above the thrust have moved generally towards the north-west. This disturbed condition of the measures becomes much less severe in the overlying Pennant ground, though there is reason to suspect the presence of more than one sharp belt of compression south of Cross Hands. Mr. Cantrill

The most important of these thrusts has been brought to light during recent years by the workings at the Park and the Rhôs Collieries, and has been proved to extend from Pontyclerc in a W.S.W. direction along Fferrws Brook past Ty-croes. It separates the Park and the Rhôs Collieries on the north from the Pantyffynnon and the Mynydd-bâch outcrops and workings on the south. Mr. E. R. Fisher* has estimated its effects as equivalent to a downthrow north of about 200 yards. In the slopes of the Ammanford Colliery, which lies a mile farther east, was found a fault which is nearly if not quite in the same line of disturbance. In the opposite or westward direction the thrust ranges for the great tract of unproved ground west of Hendre. A N.N.W. fault with a westerly downthrow, which has been estimated at 90 or 100 yards, has been proved under Myrtle Hill, near Hendre, in the Stanllyd Vein workings of Rhôs Colliery. The Pontyclerc overthrust would intersect this fault about 700 yards south of Hendre, but nothing is known as to either the effect of the intersection or the westerly continuance of the thrust.

By this overthrust the Stanllyd and other veins which crop out at Pontyclerc on the south are repeated, and crop out again to the north near the present Park Colliery. Between the latter and the outcrops in Cwm Lash there is probably another disturbance having the effect of a northerly downthrow ranging E.N.E. through or near Saron. North of this line there seem to be no breaks, but the beds are traversed by repeated rolls which have the effect of giving the outcrops of the coals a complicated sinuous course and carrying them farther and farther north. These undulations are clearly brought out both on the surface by the mapping of the Rock Vein and its overlying massive sandstone, and also underground by the forms of the workings in the Stanllyd and other veins at Blaenau, Pont Lash, Caerbryn, and Emlyn Collieries.

Another overthrust was encountered in the downcast shaft of the New Cross Hands Colliery, where the Lower Pumpquart

* "Remarks on the Mynydd Mawr Anthracite District." October, 1902. 8vo. *Ammanford.*

Mr. Cantrill. Vein was struck at a depth of 40 yards and again at the bottom of the shaft at a depth of 100 yards. It is believed to range towards the E.N.E. and to separate the Rock Castle workings on the north from those of California and Emlyn on the south.

The principal lower coals west of Ammanford are the following, in descending order :—

Gorsgôch and west.	Emlyn.	Caerbryn.	Rhôs.	Pantyffynnon.	Pontyclerc.
Big V.	Big V.	Rock V.	New V.	Upper V.	Rock V.
		Yard V.	Little V.	Little V.	Middle V.
Green V.	Green V.	Green V.	U. Pumpquart V.	U. Pumpquart V.	U. Pumpquart V.
	Cwmffaldau V.	(?)	Cwmffaldau V.	Coal 1 ft.	Coal 1 ft. 2 in.
	Bwla V.	(?)	Bwla V.	[Cwmffalda V.]	Rocket V.
Stanllyd V.	Stanllyd V.	Stanllyd V.	Stanllyd V.	Stanllyd V.	Stanllyd V.
Gras-uchaf V.	M. Pumpquart V.	M. Pumpquart V.	M. Pumpquart V.		U. Fireclay V.?
Gras-isaf V.	U. Triquart V.	U. Triquart V.	U. Triquart V.		L. Fireclay V.?
Charcoal V.	Charcoal V.	Charcoal V.			
Brasslyd V.					
Gwendraeth V.					
L. Triquart V.					
L. Pumpquart V.					
Rhâs-fach V.					

In this correlation, beside the frequent change of names, the main facts to be noted are the westerly thinning of the ground between the Rock and Middle Veins of Pontyclerc and the ultimate union of these two veins west of Emlyn as the Big Vein. Between the Upper Pumpquart and the Stanllyd Veins are two coals known as the Cwmffaldau and the Bwla; they may be represented at Pontyclerc by the 1ft. 2in. coal and the Rocket Vein respectively, assuming the Stanllyd of Pontyclerc to be rightly named, and the Bwla may be represented by the Green Vein at Pont Lash Colliery. They do not, however, seem to be present at Gors-gôch. Mr. Cantrill.

The Stanllyd appears to be unworkable at Pontyclerc and again west of Cross Hands.

The two Fireclay Veins at Pontyclerc may possibly represent the Middle Pumpquart and the Upper Triquart of Rhôs, etc.

There is much uncertainty as to the correlation of the veins at Tirydail Colliery. Comparing them with the veins below the Upper Triquart at Park and in the Caerbryn district the following seems to be a possible correlation:—

Caerbryn, etc.	*Park.*	*Tirydail.*
Charcoal V.	Charcoal V.	Supposed Cwmffaldau V.
(Brasslyd V.)	Vein 2 ft. 8 in.	Supposed Stanllyd V.
(Gwendraeth V.)	Vein 3 ft. 2 in. with clod 1 ft. Vein 1 ft.	Supposed U. Triquart V.
L. Triquart V.	Vein 1 ft. Vein 2 ft.	Supposed Charcoal V. 2 ft. 6 in.
L. Pumpquart V.	L. Pumpquart V.	L. Pumpquart V. 3 ft. 2 in. Vein 1 ft. 6 in.

The roof of the Lower Pumpquart Vein at Tirydail agrees with that at Park and at New Cross Hands in containing shells of lamellibranchs.

The foregoing suggested correlation of the veins west of Ammanford appears to bring us no nearer to a comparison of that district with the Amman Valley itself. Two boreholes at Ammanford Colliery, though agreeing fairly well in themselves, are comparable neither with the Pontyclerc section on the west, nor with that of Llwyn-yr-hâf on the east. This last, on the other hand, agrees well with Cwm Amman still farther east. All that can be said of the Ammanford section is that if the vein with numerous partings met with at 170 yards and 241 yards in boreholes No. 1 and No. 2 respectively be the Stanllyd, then the so-called Little Vein now being worked is probably the Brass Vein, and the lowest group of coals found in No. 1 borehole would then represent the Piodau Veins or Little Brass, Middle, and Lower of Brynamman.

Above the Big or Rock Vein, which must not be confounded with the Stanllyd, follows a considerable thickness of shale-ground with occasional beds of sandstone, some resembling cockshot, others Pennant. Here we should expect to find the Red Vein, but it has not been recognised. At the Red Vein workings at Ammanford a clod five feet thick comes in and divides the vein

Mr. Cantrill. the lower part was worked at the Dynevor and Maes-y-cwarau Colliery as far west as the Bettws Fault, beyond which the vein has never been recognised. It is quite likely that this parting persists westward, and if the coals at the same time deteriorate in quality and thickness, their apparent absence is explained.

At Bettws a well-marked band of cockshot rock lies about 350 feet above the Red Vein. What is probably the same rock crops out west of the Loughor at Buarthau and Pen-yr-heol, south of Ty-croes, and the calculated position of the Red Vein lies somewhere near Penygarn, where some old cropworks occur on the south side of the brook. At Clawdd-du the cockshot is thrown down west by the Hendre Fault and crops out south of Greynor, and the position of the Red Vein would appear to lie somewhere between that place and Plâs-bâch, where some thin coals have been tried in the dingle. At Cefn-Gwili the beds are again thrown down west by what we believe to be the northerly extension of the Gorseinon Fault, and the cockshot crops under the Boulder Clay of the Gwili valley north of Dingle.

West of the Gwili the crop is again thrown north to Gelli'r-odyn-uchaf by the Bryn-gwili Fault which follows the main road from Pontardulais to Cross Hands. It next appears at Pant-gwyn, near Cross Hands, and forms a bold escarpment extending thence south-westwards to beyond Tumble. The Red Vein position would lie probably half-way down this escarpment, and a small vein has been dug along the crop south-west of Llech-y-fedach which may possibly represent it.

It will be noted that the shift of outcrop from Dingle to Gelli'r-odyn-uchaf is about 1¼ miles, which indicates a large westerly downthrow. The fault apparently continues northwards to and beyond Pant-gwyn, but does not explain the reappearance of the cockshot on its west side at that place. To account for the repetition we must suppose that between Gelli'r-odyn-uchaf and Pant-gwyn there is a repeating fault—in fact, just such a structure as characterises the Pontyclerc disturbance already described. As will be shown later, the form of the ground near Blaenau-mawr strongly suggests the existence of such a fault, which not improbably is continued as the Llannon disturbance described on p. 184.

Beyond Tumble the cockshot feature is cut through at Penllwyn-gwyddau by the Morlais Valley Fault, beyond which it becomes less definite and consequently the position of the Red Vein horizon becomes still more uncertain, but a small vein, said to be one of the Carway Veins, cropping in a dingle above the Llanelly and Mynydd Mawr Railway at Cwm Blawd, may possibly represent it.

The cockshot band forms a well-marked base to a series of alternating shales and Pennant-like sandstone, containing several thin and impersistent coals. The beds are well exposed on the slopes of Mynydd Bettws, and again, west of the Loughor, north of Llanedy and Llannon. These rocks are not distinguishable lithologically from the Pennant series, though for reasons explained elsewhere the Rhondda No. 2 Vein was selected

in the eastern part of the coalfield as the base of the Pennant. The rocks in question would thus correspond to the Llynfi Rock of the Maesteg district. Mr. Cantrill.

The Garn Swllt Vein on the east of the Loughor near Pantyffynnon is the only representative we can find of the vein which, farther east, on Mynydd Gwrhyd, may with much certainty be regarded as the Ynysarwed or Rhondda No. 2 Vein.* In the district examined during the past year a thin seam occurs in about the right position for that vein, with another seam above it, both having been worked by the farmers at one place or another. The lower seam has been recognised in Llanedy from Gelli-organ to Pentre-hardd, and in the dingle west of Bryn-bargod. In the Gwili valley it is thrown north by the Bryn-gwili Fault, apparently to Ty-gwyn, where a small vein has been worked. Thence the crop trends southwards to near Ty'r-ffynnon, but is soon faulted north again.

Between Ty-gwyn and Llannon there is evidence of lines of disturbance, one ranging S.S.W. past Blaenau-mawr. This makes its appearance in the Gwili river at Cwm-uchaf, three-quarters of a mile below Cross Hands, as a belt of steeply-dipping beds, the strike of which trends thence in a S.S.W. direction along a well-marked hollow to beyond Blaenau-mawr, and separates the shale-ground below the cockshot on the east from the sandstone-ground at Bryn-mawr and Pen-twyn on the west. This latter area is possibly separated by a second disturbance from the long promontory of Twll-y-car and Llwyn-cwta. Around this promontory run two veins exposed at Llwydcoed-fawr. The lower appears to fall in with the calculated position of Rhondda No. 2. The Tumble Fault, an upthrow west, shifts the outcrop to the south, and the coal formerly worked at Pentre is probably one of the two. West of this place the Morlais Valley Fault throws the ground down on the west, and the vein occasionally worked north of Pen-llwyn-uchaf and running thence towards Bryn-gwyn may be the lower of them. It is next seen skirting the west flank of Mynydd Sylen, and is being worked near Farm-fach. The crop passes near Maes-llydan, and comes to the surface in an inlier at Cockpithall, while there are outliers at Cynheidre and Brondini. The Pennant series above this horizon presents the usual characters of dirty sandstone parted by shales which rarely exceed 100 feet in thickness. The coals are used only for local purposes and are of little value.

SOUTH WALES COALS.

It having been decided that it was desirable to obtain information with respect to the changes undergone by the seams of coals of the South Wales Coalfield, arrangements for the collection of samples were commenced in 1901. The coal varies from house-coal, through an intermediate stage known as steam-coal, to Mr. Strahan.

* Summary of Progress for 1900, *Mem. Geol. Survey*, p. 95; also *Ibid.* for 1901, p. 44.

Mr. Strahan. anthracite. A large number of analyses had been made, partly in connection with an official report in 1848 by De la Beche and Playfair on "The coals suited to the Steam Navy," partly by public analysts for commercial purposes; but many of these analyses are useless for the present purpose for two reasons, 1st—that the name of the seam is not always given, 2nd—that they have been made by different methods and are not comparable.

The facts reported with respect to the change undergone by the seams are as follows:—

1st. The anthracitic regions lie in the north-western corner of the Carmarthenshire, Brecknock, Glamorganshire field, and in Pembrokeshire. In the former which we may call the main Coalfield, the seams become gradually more bituminous in receding from the anthracitic region. The change takes place from N.E. to S.W. at the west end of the basin; from N. to S. near Swansea; from N.W. to S.E. towards Cardiff; from W. to E. along the North Crop. In other words lines of equal anthracitisation circle round an area, the centre of which must lie between Kidwelly and Llandybie.

2nd. The seams all show the change on approaching the anthracitic region, but the shallower seams show it later. Thus, No. 2 Rhondda Coal keeps its character as a house-coal to within about 25 miles of the anthracitic centre, and then becomes a steam-coal. The lower coals, about 400 yards below, become steam-coals about 30 or 40 miles from the anthracitic centre, and then occur as anthracites for a distance of about 25 miles. In a southerly direction the change from one type of coal to the other is far more rapid, but beyond the fact that the lower seams are highly bituminous in the South Crop and pure anthracites at 12 miles distance in the North Crop, nothing is known.

It will be noticed that in any one deep shaft the upper seams should be more bituminous than the lower. Not only has this been found to be the case, but some of the larger faults are known to throw in bituminous coals in a steam-coal region. From the fact that the anthracitisation is more rapid in a north and south direction it may be inferred that the area of presumed regional metamorphism is elongated in an east and west direction.

There have been many speculations on the cause of the loss of bituminous matter. It has been attributed to the faults, but the evidence produced was unsatisfactory for various reasons.

The analyses were neither sufficiently numerous nor reliable to prove it, while the fact that there are three systems of disturbance, two at least of which differ widely in age and character, was not taken into account. That the anthracitisation was not due to the pre-Triassic disturbances can be proved repeatedly in the South Crop, where the coals, though plicated and vertical, are bituminous. Again, the fact that some of the N.N.W. faults throw bituminous coals against steam-coals indicates that the bituminous matter had been lost before the faults came into

existence. On the other hand there may be a connection between the anthracitisation and the E.N.E.–W.S.W. system of disturbances. The anthracitic area coincides with the region in which those disturbances are developed, it is elongated in the direction in which the disturbances range, and, lastly, the anthracitisation increases in intensity towards the region of maximum disturbance. Mr. Strahan.

It has been suggested also that the anthracitisation has been brought about by heat, and that the heat was due to the coals of the anthracitic regions having been more deeply buried than other parts of the Coal Fields. Stratigraphical evidence, on the contrary, points to the bituminous regions having been the more deeply buried, both under later Carboniferous and Secondary Rocks.

The principal objects for which the series of analyses now in progress is wanted are:—

For the purpose of drawing lines of iso-anthracism for each of the principal seams, and of defining the areas occupied by house-coal, steam coal, and anthracite, in the unproved parts of the Coal Field. This is a matter of the greatest economic importance.

Of investigating the possible connection of the loss of volatile matter with any of the systems of faulting or folding.

Of forecasting whether the upper seams in the "steam-coal condition" may be expected to be of the same value as the lower coals which are now worked as steam-coals in the Rhondda Valleys.

Arrangements were commenced for the collecting of "Samples of Coal" in January, 1901. The advice of the South Wales Institute of Engineers had been sought, with the result that a Committee was formed of gentlemen representative of every part of the Coal Field, who undertook to communicate with the colliery-proprietors and seek their consent to the collecting and analysing samples of their coal. It was arranged that the analyses should be published, but that the localities from which the samples were obtained should be indicated by numbers only on a general map of the Coal Field, and that the names of the collieries should not be mentioned.

The first collection of coals was made in 1901. It was arranged that the collector should be conducted at every colliery to a working face, where a typical development of the seam was exhibited, and that coal should be cut by a colliery-official from all parts of the face, except those partings which are separated out by the miners. The coal thus cut was sampled by the collector in the usual manner and enclosed in a box with a printed form filled in by the colliery-manager, on which were given the name and section of the seam, depth from surface, and other particulars. Eleven samples were collected in 1901, and a second collection of ten samples was made in 1902. Among these samples the three principal varieties of coal are represented, namely, bituminous house-coals, steam-coals, and anthracite. Ten samples from the first collection have been analysed. The method of analysis is discussed by Dr. Pollard in the *Summary of Progress for 1901*, pp. 72–80.

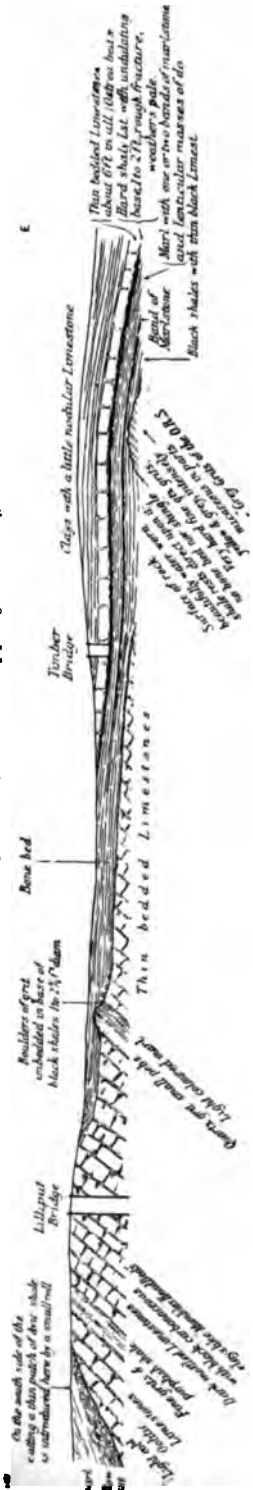
Thin bedded Limestones about 60ft in all, the two hard shaly bands 1st with undulating base to 2ft. rough fracture, weather's pale
Marl with one or two bands of marlstone and lenticular masses of do
Bands of Marlstone
Black shales with thin black Limest.
Thin bedded Limestone
Tunnel
Tunnel Bridge
Bone bed
Boulders of grit imbedded in base of black shales 1to2½ Feet
Thin bedded Limestones
Lilliput Bridge
On the south side of the cutting a thin patch of dark shale is overlaid here by a small fault

FIG. 9.—*Railway-cutting near Chipping Sodbury.*

V.—CUTTING ON THE SOUTH WALES DIRECT RAILWAY, NEAR CHIPPING SODBURY.

BY A. STRAHAN, M.A.

By the courtesy of Mr. B. A. Baker, the Directors' attention was called to the further opening of the new section in the South Wales Direct Railway near Chipping Sodbury, previously reported on by Messrs. Woodward and Strahan,* and the section was re-visited in July.

The cutting traverses a ridge of Carboniferous Limestone which projects through the Secondary Rocks. It discloses the history of the gradual submerging of the ridge under Triassic and Liassic waters.

On the west side of the ridge Keuper Marl, with irregular deposits of yellow dolomitic limestone, rests directly upon the limestone. Its thickness, however, was not great, for a small roll down to the west suffices to bring in some of the over-lying *Avicula contorta*-shales on the south side of the cutting. The marl, dipping westwards, ends off about 200 yards west of Lilliput Bridge, and the cutting then shows Carboniferous Limestone up to the surface as far as, and a few yards east of, the bridge. About 20 or 30 yards east of Lilliput Bridge the *Avicula contorta*-shales come in again, but this time without any Keuper Marl intervening between them and the Carboniferous Limestone; nor indeed does the marl occur anywhere in the cutting east of the bridge. The shales, slanting gently down eastwards with what is as likely to be a slope of deposition as a dip produced by subsequent movement, rest upon a remarkably smooth and even floor cut out from the highly inclined Carboniferous Limestone. In one place only a hard grit, interbedded in the limestone, projects above the general level, and it is interesting to note that for a short time the crag formed a small Rhætic island from which blocks of grit rolled down into the earliest Rhætic

* Summary of Progress for 1898, p. 191.
There is a brief reference to this cutting in a paper by Messrs. S. H. Reynolds and A. Vaughan, *Quart. Geol. Soc.*, vol. lviii., p. 727 (1902).

sediments. Before the close of the Rhætic period the crag was submerged and its site smoothed over by the uppermost bands of shale. Two hundred yards east of it there is a small pocket showing the Rhætic Bone-bed in characteristic form.

The Lias commences 400 yards east of Lilliput Bridge, and the cutting then yields the following measurements:—

		ft.	in.
Lower Lias	Shale with a thin limestone, seen to	40	0
	Thin-bedded limestone with shale-partings (*Ostrea*-beds)	6	0
Rhætic Beds	Hard limestone with undulating base; rough shelly fracture; weathers pale* 1 ft. to	2	0
	Pale-blue shaly marl 5 ft. to	6	0
	Pale-coloured marl-stone	1	0
	Very pale marl, containing masses of harder marl-stone	6	0
	Shale, darker	1	0
	Dark limestone and "bref"	0	3
	Dark shale with *Avicula contorta*	8	0
	Carboniferous Limestone	—	

These various bands and especially the hard limestone with undulating base can be traced along the sides of the cutting eastwards, that rock finally sinking to the level of the rails 800 yards east of Lilliput Bridge. A slight undulation, however, was apparent at a point 150 yards short of its disappearance, which might have suggested a gentle anticline, had not the bottom of the cutting revealed the true cause. The undulation marks the site of a submerged crag formed by a fine-grained but extremely hard quartz-grit, yellow and grey in colour and intensely micaceous. Like the crag previously referred to, this rock formed an island temporarily in the Rhætic water, but was submerged and buried before the Rhætic period closed. Its surface still shows the effect of Rhætic waves. Though there are no shingle or boulders, its outlines are beautifully water-worn. The rock obviously belongs to the Old Red Sandstone, and without much doubt to the uppermost subdivision of it.

Retracing our steps we may note the sequence in these older rocks. They dip uniformly westwards at about 40°. Between the crag of Old Red Sandstone and the nearest exposed limestone (as shown in July) there is a gap of about 150 yards, in which presumably there would be found a natural junction between the two formations. For about 300 yards the cutting then traverses thin-bedded limestones, and reaches a light-coloured marl overlain by a quartz-grit with small pebbles which forms the crag first described. On the west side of Lilliput Bridge there occur, still in ascending order, dark mottled limestone with black carbonaceous beds, which recall the Mumbles Head Beds of Gower,† and then fine grit and purplish shale, followed by light-coloured oolitic limestones. Here we lose sight of the older

* Messrs. Reynolds & Vaughan note here the Sun-bed and underlying Cotham Marble.

† Summary of Progress for 1901, p. 41.

rocks under Keuper Marl, but from the fact that shales occur west of Chipping Sodbury nearly on the line of strike of the limestone last seen, we may assume that we are not far from the top of the formation. The shales referred to have been disclosed in working pockets and veins of "strontian." Its occurrence in rock of Carboniferous age is doubtless due to the fact that the Keuper Marl lay immediately overhead, The mineral is found down to a depth of not more than 6 or 8 feet.

The absence of the Keuper Marl in the eastern part of this section suggests a difficulty. It may be assumed that the areas where the *Avicula contorta*-shales rest directly upon the old rocks were above water during Keuper times; that is to say, the eastern part of the section must have stood higher relatively to the western part than it does now. But the Keuper Marl already has a strong westerly dip. The raising of the eastern part of the section involves an increase in this dip. Had the material been breccia the dip might have been attributed to "slope of deposition," but it hardly seems probable that marl and limestone could be lain down in strata so far from horizontal. A fault with a downthrow east would explain the circumstances, but no such fault has been detected.

VI. The Woodford and Ilford Railway.

BY J. ALLEN HOWE, B.Sc., F.G.S.

This new line leaves the G. E. Main Line opposite the Ilford cemetery and continues in a northward direction as far as Grange Hill where it bends sharply to the west for Woodford. The shallow cutting north of Cauliflower Lane, shows a thin covering of loam, 2 to 3 feet, on gravel; for 200 yards north and south of Ward's Lane the loam is absent, only gravel, with sand-layers, being present. At a point some 300 yards south of Hatch Lane Station (for Ley Street) the cutting passes through the thin strip of gravel-covered London Clay, which here separates the lower from the higher terrace. From the Station to the stream north of Ley Street is a good section in the high terrace gravel; near the School there is a thickness of about 15 to 20 feet of gravel upon 8 to 10 feet of London Clay with septaria. The gravel maintains its thickness to the north end of the cutting but rapidly thins southward, till at the Station it has almost disappeared. Across the broad gravel terrace of Fairlop Plain there are no exposures; the line leaves the gravel and enters the London Clay of the rising ground about half a mile south of Manor Road Station. In the tunnel of Grange Hill, and the deep cutting under Hainault Road, London Clay alone is exposed; except that there is a sprinkling here and there of gravel-wash from the higher ground of Tom's Hill.

A short account of the geology of the line has been written by Mr. T. V. Holmes, F.G.S.*

* *Essex Naturalist*, vol. xii., pp. 202-206.

VII. Notes on the Occurrence of Natural Gas at Heathfield, Sussex.

By H. B. WOODWARD, F.R.S.

In a paper read before the Geological Society of London in 1898, Mr. Charles Dawson directed attention to the discovery of Natural Gas in East Sussex.*

Referring first to the reported issue of inflammable gas in the deep boring made at Netherfield, near Mountfield, for the Sub-Wealden Exploration, and which was (1875) attributed to the petroleum-bearing Kimeridge Clay, Mr. Dawson then gives particulars of the discovery of natural gas at Heathfield.

In 1895, when a boring was made in search of water at Heathfield Hotel, the foreman of the work found that inflammable gas was being given off at a depth of 228 feet. No special interest appears at the time to have been taken in this discovery, and as no supply of water was obtained the boring was abandoned.

In the following year another boring for water was made by the London, Brighton, and South Coast Railway Company, by the side of the railway between Heathfield Station and the tunnel to the north-west. This boring was abandoned at the depth of 377 feet, as "no useful amount of water" was obtained. At the depth of 312 feet there was, however, a rush of gas so pronounced that it was tested, and a flame of about 16 feet in height was the result. A strong odour of gas had been noticed at lesser depths, and below 312 feet it "continued to increase during the remainder of the depth bored." No immediate steps were taken to utilise the gas, indeed the wrought-iron tubes were withdrawn from the borehole, with the exception of about one-length which was left in the ground.

Experiments made in 1898 having proved that the quality of the gas was suitable, and that the pressure and supply were maintained, the gas was in 1899 utilised in lighting up the railway station and subsequently for other purposes.

The possible importance of the gas-field did not, however, arouse public interest until the present year when the company entitled "The Natural Gas Fields of England, Limited," commenced a series of borings at Heathfield and at Mayfield. As a result, the village of Heathfield has been lighted from one of the bore-holes, and pipes have been laid down for the supply of Polegate and Eastbourne.

Five borings have now been made or are in progress between Heathfield Station and Britannia Mill, and a sixth is in progress by the eastern side of Waldron Gill, rather less than half a mile south of the station. Through the courtesy of Mr. Inverness Watts, engineer to the company, I was enabled to visit the sites. Gas had been found in all but one (No. 5) of the bore-holes. Unfortunately the borings are made by means of a "jumper" and the material is brought up as sludge, mostly a silty clay, so

* *Quart Journ. Geol. Soc.*, vol. liv. p. 564; and *Proc. Geol. Assoc.*, vol. xvii. 1901, p. 171.

that details of the strata cannot be ascertained and recorded with anything like the precision that was possible with the cores from the two earlier borings, made by Messrs. Le Grand and Sutcliff. On those borings we must rely chiefly for our knowledge of the strata.

Summarised, the particulars are as follows*:—

	Heathfield Hotel 493 feet above OD.	Thickness.	Depth.
Ashdown Sand.	Sand with lignite and marl (Dug Well)	21	21
	Sandstone and marl	11	32
	Sandstone	18	50
	Sandstone and marl	21	71
	Sandstone	5	76
	Sandstone and marl	18	94
	Marl	57	151
	Sand-rock	4½	155½
	Marl with stone-band	60½	216
	Sand-rock	3	219
	Marl	30	249

Gas noticed at 228 feet.

	Heathfield Station 450 feet above OD.	Thickness.	Depth.
Fairlight Clays and Ashdown Sand.	Dug Well	73	73
	Sandy marl-rock, lignite and ironstone	67	140
	Hard sandstone	1¾	141¾
	Sandy marl-rock, ironstone	19¾	161½
	Sandstone	1¼	162¾
	Marl-rock, sandstone and ironstone	9¼	172
	Sandy marl-rock and ironstone bands	24¼	196¼
	Marl and sandstone	22¾	219
	Sandy marl-rock and sandstone	45½	264½
Purbeck Beds.	Marl with bands of marble	2½	267
	Marl and shale and marl rock (*Paludina*)	72	339
	Marl-rock, bituminous shale, shells	14	353
	Marl, shale and shell-rock	24	377

Gas first lighted at 312 feet.

Mr. I. Watts informed me that in the new borings gas is found to issue at about 280 feet, sometimes when hard iron-stone bands are pierced. The pressure at Heathfield Station was stated to be equal to 200 lbs. to the square inch, and this had not been modified by the subsequent borings. The quality is so good that no refining is necessary.

Heathfield Station is in Waldron Parish, and the newer part of the village of Heathfield extends to the north-east and south-east of the station, at the head of a fine valley which opens out to the south-west and is drained by Waldron Gill. The ground rises on the north to 600 feet near Mutton Hall, and to the south to 598 feet at Gibraltar Tower in Heathfield Park. These higher and well-wooded grounds are formed mainly of sandstones which dip northwards (as shown on the Geological Survey Map) on the north, while in Heathfield Park the beds are inclined to the south-east. Thus the anticline which brings in the Purbeck

* Dawson, *op. cit.*, pp. 569-571. See also Water Supply of Sussex, *Geol. Survey*, pp. 87-89.

Mr. Whitaker has grouped all the beds at Heathfield Station down to 339 feet with the Fairlight clays.

beds further east along the course of the River Dudwell, probably extends in a north-westerly direction through Tilsmore Wood; and Heathfield Station would be on the southern side of the anticline, with perhaps an inlier of Lower Wealden (Fairlight) clays and sands in the Waldron Gill valley to the south-east.

The district may be affected by more faults than are shown on the Geological Survey Map, but if the dip, as above stated, is maintained, it is probable that all the six borings have been commenced in approximately the same strata—perhaps No. 5 in slightly higher and No. 6 in slightly lower strata than those of the four other borings.

The strata exposed in the banks of Waldron Gill, below the site of No. 6 Boring, comprise thin-bedded sandstones with harder bands of ferruginous sandstone, and these are bent in one spot into a sharp fold. Lignite has been dug in the bed of this brook. *

In general the beds here comprise sandstone, fine sand, lignitic sands, white sandy clay and purplish clay. The brickyard south of Heathfield Station exposed whitish clay and sands in thin alternating beds.

In the two quarries in the north-west of Heathfield Park, 12 to 15 feet of thin fissile sandstones, with bands of pale purplish and whitish clay, overlie thick-bedded sandstone much jointed and also false-bedded. The soil made up of the alternating fine sands and clays is impermeable in places, so that water stands here and there in pools in wet weather, and the roads are wet and silty. The thick-bedded sandstones above noted would be well adapted to store gas under favourable circumstances. They are, however, above the horizon of the strata penetrated in the Heathfield borings.

Beds on the horizon of those bored into at Heathfield are exposed on the borders of the deep valley east of Heathfield Park, where also the Purbeck Beds come to the surface, at a distance of rather less than two miles from Heathfield Station. North of Punnett's Town, to the east of Cade Street, ferruginous sandstone and loam and fine-grained sands and sandstones are observable on the way from Lucks' Farm to Little Greenwood.

Further on to the east of Greenwood Farm purple and mottled clays are exposed, while south of the Ford on the River Dudwell, on the trackway from Three Cups Corner to Pounceford or Poundsford, there may be noted in descending order:—

Wealden—	Yellow sandstones and clayey beds.
(Fairlight Clays)	Grey and purplish clay.
Purbeck	Leathery shales.

On the north side of the Ford, Purbeck Beds were shown having a high northerly dip, but there is little doubt that the beds are disturbed by landslipping. Shelly limestone and shale

* See Topley, Geology of the Weald, pp. 347, 348.

and compact limestone here occur, and higher up leathery shales like those seen south of the river. The intermediate ground has cappings of grey and ferruginous clay with blocks of Wealden sandstone, suggestive of a southerly dip, and of the crest of the anticline being a little north of the Dudwell, an inference supported by dips marked on the Geological Survey Map.

On the hill above Poundsford the beds have a northerly dip, and the section is like that of the quarries in Heathfield Park. Fine white sand, sandy clay and ferruginous sandstone in thin layers, overlie thick beds (3 or 4 feet) of yellow sandstone, much jointed. These beds appear to be slightly faulted, but are more probably displaced by landslip on the brow of the hill. The bold features north of Poundsford are formed by the strong beds of sandstone, and had there not been considerable faulting and downthrow of Wadhurst clay and Tunbridge Wells sands, the Purbeck Beds might again have appeared further north in the valley of the Rother. As it is Mayfield, where another boring is being made, is on Tunbridge Wells sands and sandstone. These are much more evenly bedded than the Ashdown sands of Heathfield, but they also have sandy clay partings.

The leathery shales which occur in the upper part of the Purbeck Beds at Poundsford are distinctly bituminous. Specimens have been tested by Dr. Pollard.

Attention however was directed to this fact by Topley, who stated in 1875 that Mr. R. Hallett, then owner of Swife's Farm, near Burwash "had several tons operated upon, from which was extracted in the first instance tar, and by subsequent processes a variety of products such as pitch, grease, oil, naphtha, and paraffin."*

Topley also called my attention to the fact that the gypsum at the works at Netherfield becomes bituminous along a line of fault.†

Again, in the Kimeridge Clay at the Sub-Wealden Boring, a "hard light-coloured bed, very rich in petroleum" was passed through at depths of 600 to 602 feet,‡ and bituminous shales again occurred from 960 to 1000 feet.

The information which is before us indicates that a certain amount of natural gas is pent up in the Lower Wealden Beds and in the Purbeck Beds. The bore-holes, however, have not penetrated any thick masses of porous strata such as we might judge capable of storing a vast accumulation of gas. What has been obtained must have been stored in comparatively thin layers of sandstone and sand interlaminated with the Wealden clays, and in the harder bands of the Purbeck.

It appears, therefore, that gas is derived from Purbeck shales and that it may be stored over a considerable area in the thin porous beds. The Portland Beds identified in the sub-Wealden Boring have been somewhat differently described in the several

* Geology of The Weald, p. 38.

† Jurassic Rocks of Britain, vol. v., p. 331.

‡ Geology of the Weald, p. 43.

records which have been published. That given by Topley in Dixon's Geology of Sussex* is noted in the accompanying general table.

General Section of the strata in the Heathfield District.

		Feet.
Ashdown Sand with Fairlight Clays 350 to 400 feet.	Sands, sandstones, loamy sands, shales, and clays —on the whole more clayey towards the base (= Fairlight Clays)	
Purbeck Beds 400 feet.	Shales, etc.	30
	Limestones, calcareous sandstones and shales	50
	Shales and clays with occasional stone-beds	130
	Limestones and shales	75
	Shales with occasional stone-beds	35
	Shales with gypsum	80
Portland Beds 115 feet.	Sandy shale	23
	Soft whitish sandstone	52
	Darker sandstone	5
	Sandy shale	35
Kimeridge Clay 1273 feet.	Shales with septaria, etc.	668
	Bituminous shales	40
	Clays and sandy beds	4
	Sandstone	41
	Sandy shale, etc.	47
	Shaly sandstone	45
	Limestone	45
	Shale	94
	Limestone	29
	Shale	20
	Grit and limestone	45
	Limestone and shale	27
	Shale	23
	Limestone	10
	Shale	135

Here, below the Purbeck Beds, we have evidence of important beds of sand and sandstone 50 to 60 feet in thickness, and capable of storing a great quantity of gas.

At present these strata have not been penetrated in any of the bore-holes in search of natural gas, and it would seem necessary to bore from 300 to 320 feet deeper at Heathfield to reach this horizon.

It is possible, however, that gas from these Portland Beds may have been indirectly tapped through crevices and fault-planes, but on this point nothing definite can be said.

The absence of water from the strata may be due to the presence of the gas, and water may replace it as it escapes.

VIII.—On the Drifts of the Thames Valley near London.

By T. I. Pocock, M.A.

The drifts of the area surveyed in the past year consist of Boulder Clay, gravel sand, brickearth, and alluvium of various ages from the climax of the Glacial period to recent times.

* Ed. 2, p. 154, see also pp. xxiii. and 6 ; H. B. Woodward, Jurassic Rocks of Britain, vol. v., p. 229 ; Water Supply of Sussex, pp. 65–70. The boring is at Mountfield.

These deposits will be described as far as possible in the order of their age.

The oldest of the drifts is the Boulder Clay with some associated beds of brickearth, which are found near Upminster, in Essex. They occupy a very small area but are of great interest as showing the relation of the Thames valley to the Glacial period. The best section to be seen is at some brick and tile works a mile and a half north of Upminster Railway Station.* The brickearth is worked in two pits, one on each side of the lane which runs eastwards from "Martins" Farm (v. one-inch map). The pit on the south side of the lane shows about 20 feet of brickearth with a few seams of small gravel. It is sandy and finely laminated in the lower part, but tough and more homogeneous above. It is evidently a water-formed deposit, but the occasional contortion of the laminæ seems to indicate disturbance by ice-floes. The brickearth thins away suddenly on the west side of the workings, and Boulder Clay rises from beneath it. In some shallow, almost overgrown pits nearer the main road there is a section of clay 2 or 3 feet thick containing abundant unworn flints and pieces of chalk together with quartzite pebbles and subangular blocks of sandstone, some of which are smoothed and striated. The base of the Boulder Clay is no longer exposed, but according to the information of the foreman of the brick works, the chalky clay rests upon a variable bed of sand a few feet thick, under which is a tough clay full of stones but containing no chalk.

In the working on the north side of the lane the Boulder Clay is wanting. The brickearth is about 15 feet thick and rests directly on London Clay. On all sides except the west the brickearth has been cut round by denudation so that its original extent is uncertain. It is probably an older deposit than the great mass of brickearth at a lower level in the Thames valley, indeed, its association with Boulder Clay suggests that it is part of an old glacial lake deposit. No organic remains have as yet been found to confirm this view. The level of the Boulder Clay at this point is about 150 feet above ordnance datum. Several outliers of stony clay have been traced in this neighbourhood, some of which still contain a little chalk, and others are probably decalcified remnants of the chalky Boulder Clay. They are found on both sides of the Ingrebourne brook from 50 to 100 feet above the bottom of the valley, and gradually increase in elevation as they are traced northwards. Doubtless they are the remnants of a continuous bed of Boulder Clay, which stretched from the high ground separating the valleys of the Roding and the Ingrebourne southwards into the Thames valley. The lowest point at which the Boulder Clay has been found is in the railway cutting between Romford and Upminster

* See Whitaker, Geology of London, Vol. i., 1889, p. 415. The pits with Boulder Clay have been opened in recent years and seem not to have been previously described.

where it descends beneath the river gravel at about 80 feet above sea level.*

Hence we are led to the conclusion that the greater features of the Thames valley were formed before the climax of the Ice Age. The bottom of the main valley in Essex was no more than 80 feet above the present sea-level, and the broader tributary valleys had already been carved out. It is known that the Boulder Clay reaches the summits of the hills near Brentwood,† but is absent from the Warley hills, which rise to a less elevation between Brentwood and the Thames valley. It is doubtful whether the ice crossed these hills and descended *en masse* into the river valley. The small quantity of Boulder Clay, which is restricted to the lower slopes, would rather indicate that the ice sheet was broken up into branches, one of which pushed its way glacier-like through the open valley west of Warley, and perhaps came to an end at the ancient margin of the Thames.

What was the extreme limit of the ice has not been ascertained. There are some indications of Boulder Clay at North Ockendon, but no section could be found to prove that it is actually there. It may be that the Thames valley was still further cut down in pre-glacial time, and was filled up again subsequently by deposits of gravel. But there can be no doubt that much denudation of the Cretaceous and Tertiary formations, as well as of the gravels, was effected by the Thames and its tributaries long after the dissolution of the ice sheet.

The next series of deposits which have to be described are the Gravel Drifts. Their character is well known from the writings of many geologists, and it will suffice to state briefly that they consist of masses of subangular flint with a varying admixture of pebbles derived from the Tertiary formations, and a few igneous and sedimentary blocks from distant localities. Occasionally large boulders are found in them. Intercalations of sand are frequent and the deposits are on the whole stratified, though the bedding is often much confused.

The oldest of the gravels, which has been examined in the past year, covers some of the lower plateaux west of the metropolis.

The Boulder Clay of the south-eastern counties is frequently underlaid by beds of sand and gravel, and beyond the limit of the Boulder Clay itself, wide tracts at a considerable elevation are covered by like deposits of approximately the same age. These gravels show clearly the action of water, and they are not essentially different from the gravels at lower levels which are confined to the river valley. Whatever is the cause of the one is in some measure the cause of the others. But the wide extent of these plateau gravels shows that they could not have been formed by rivers confined to their valleys. They

* T. V. Holmes, *Essex Naturalist*, vol. vii., Nos. 1-3.

† H. B Woodward in Whitaker's Geology of London, vol. i., p. 325; see also Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlvi. Pl. vii. Fig. 5.

are comparable to the broad tracts of fluvioglacial gravel which spread northwards from the external moraines of the old Alpine glaciers. The normal drainage of the Thames valley was obliterated, and the tumultuous waters which escaped from the edge of the ice sheet, combined with the streams which flowed from the snow-clad hills to the south, overspread the country far above the level of the preglacial river. The surface on which the fluvioglacial gravels rest is an uneven one. In some cases they pass down the slopes so far that it is impossible to separate them from the valley gravel of the upper terrace. Thus, in the neighbourhood of Hillingdon, Mr. Howe found that the gravel rises apparently without intermission or break from about the 100-foot contour to 190 feet in the village.

The gravel on Uxbridge Common lies at an elevation of 205 feet and a little farther north at Harefield it reaches 222 feet. At Iver the same conditions obtain; the gravels in the village at 130 feet extend downwards, beneath the brickearth, to the 100-foot contour, and upwards towards Iver Heath at 176 feet and beyond. Again at Wimbledon Common (180 feet) the lower part of the hill consists of London Clay capped by a small outlier of Bagshot sand. The plateau itself consists of gravel which not only completely covers the Bagshot outlier but extends for some distance down the slopes of the London Clay. A similar disposition of the gravel has been noticed by Mr. Spurrell on the south bank of the river in Kent.

Enough has now been said to show that the Thames basin had been deeply eroded before the deposition of the plateau gravel which has just been described, and that its elevated position is due to a subsequent rise of the water to that level during the glacial period. No gravel corresponding to the fluvioglacial gravels of Middlesex has been found on the Essex side of the Thames as far east as the survey has been carried. Probably none was deposited there because much of that region was occupied by the ice sheet itself. By the time the ice had been washed away the waters had sunk and were accumulating gravels at a lower level.

The gravels of later date can be divided into three terraces, which can be traced all over the ground, though they are much less distinctly separated in some parts than in others. In character the later gravels are essentially the same as the fluvioglacial gravels, but they differ in being confined to the limits of the river valley. It is doubtful, however, whether this distinction will hold good when the terraces are traced eastwards along the estuary of the Thames. The terraces will for convenience be described as upper, middle and lower.

The upper terrace is poorly represented in the part of our area which lies east of Hornchurch. But small outliers are found resting on the Chalk at Grays and on the London Clay at Aveley. The same gravel apparently rises from beneath the brickearth near North Ockendon. But from Hornchurch westwards the terrace can be traced along the slopes of the Thames valley as far as Uxbridge and beyond, though there are large

gaps where the tributary streams have cut it away. On the south side of the river it occurs as small outliers near Chertsey, Weybridge, Richmond and at various spots in the north of Kent. The channel in which this ancient gravel was deposited, is about seven miles broad in Essex between the Laindon Hills and London. Between Westminster and Richmond it is reduced to less than five miles, but it expands again westwards till it reaches a maximum of fully 10 miles in a north and south line through Southall. Still further west the breadth decreases till it is only about a mile at Cookham.

Throughout the forty miles from Staines to Grays, the upper terrace maintains the same average height above the sea level. Its under surface varies from place to place, but generally speaking it is at about the 100-foot contour line near its margin. Towards the centre of the old channel, as at Brentford and North Ockendon it descends to a lower level. But no general inclination of the terrace can be traced as it is followed down the valley towards the sea. On the other hand there is a slight fall in level between Maidenhead and Staines. Hence we may conclude that the inland portion of the old river ended somewhere between these two places, and that for the rest of its course it flowed at the sea level, like the tidal part of the modern Thames, or else that it formed a broad lake-like expansion, which was held in by a barrier separating it from the open sea. If the upper terrace were extended along the valley into Eastern Essex. it would pass into an extensive gravel deposit in the neighbourhood of Colchester which is of glacial age, since it can be traced under the Boulder Clay. It is not improbable that the two are equivalent, and that while the 100-foot terrace was forming in the Thames valley, the ice still lingered in Eastern Essex, though it had disappeared from the immediate neighbourhood of London. The difficulty of separating the fluvioglacial gravels from the upper terrace has already been mentioned. Probably the deposition of gravel was continuous in some localities, while at others considerable erosion took place between the formation of the two deposits.

After the formation of the upper terrace there ensued an epoch of river erosion, during which the valley was cut down to the extent of 40 feet or more. The upper terrace was broken up, and the underlying formations in many places exposed at the surface. Whether any of the superficial deposits belong to this epoch of erosion it is not easy to say. No fluviatile gravel can with certainty be assigned to it, but possibly some of the brickearth deposits which overlie the upper terrace may have been formed on the valley slopes when the river was cutting its way through the gravel. Be this as it may, after the erosion had lowered the valley to 40 or 50 feet above the present sea level, another epoch of gravel accumulation began. This deposit is of the same character as the upper terrace, but is confined to much narrower limits. Here and there it contains thin beds of sand and loam, which are much disturbed, perhaps by the action of ground ice. In one section at Hampton, where the gravel has

been cut through, the London clay underneath seems to have been ploughed up by the same agency. But such phenomena are less conspicuous than in the upper terrace. The middle terrace forms a broad expanse on the north side of the Thames in Essex, and again between Brentford and the Colne, but it is much less extensive on the south side of the river. Often there is no middle terrace between the upper and lower. As in the case of the higher formation, the 50-foot gravel occupies the same average level in Essex as it does in Middlesex, but at Maidenhead it is considerably higher. North of Purfleet and Grays it follows very nearly the 50-foot contour. In the tributary streams further west the underlying London Clay can generally be seen rising gradually from south to north to a little over 50 feet. Near Isleworth and Hampton the London Clay has been exposed by denudation in several places at a level rather below 50 feet, and again at the northern end of the Staines reservoir the London Clay was touched at nearly the same level. During the formation of this gravel, the river flowed to the north of the chalk ridge, which extends from Purfleet to Grays, and probably the present channel to the south of that area had not been excavated. But elsewhere the river followed its present course, though it was much wider than the modern Thames. The inland portion of the river probably extended further east than at the time of the 100 foot terrace. But between Staines and Grays a uniform level was maintained, which, as in the former case, may have been the sea level of the time. Whether the terrace can be traced round the coast into fluvioglacial gravels has not been ascertained. Yet its character shows that it is a deposit of the same kind—that is to say, it owes its origin to the floods which resulted from the melting of accumulated snows on the hills.

After the formation of the 50 foot terrace there followed a second epoch of valley erosion. The gravel flats were left bare, and the river, flowing in a narrower channel, gradually cut down its bed to a level not far above the present high water mark. It is to this period that the greater part of the brickearth of the Thames valley belongs. It covers a large part of the middle terrace between Upminster and South Ockendon, and extends beyond the limits of the gravel on to the London Clay. In Middlesex it is more strongly developed, and covers indifferently all the three terraces. Prestwich long ago compared the brickearth to the Löss of the Rhine Valley* and other parts of Central Europe. Like that deposit it owes its origin to different agencies and probably also to varying conditions of climate and geography extending over a considerable space of time. Moreover, it belongs to more than one distinct epoch. Some of the deposits may be older than the middle terrace, as has been seen already. Others are younger than the later terrace for they form thin sheets covering the lowest gravel near the river in Middlesex, and probably pass up the slopes over the

* *Phil. Trans.* 1864.

older brickearths. Sections of this later brickearth can be seen near Shepperton Railway Station and at the Brick Works, Upper Halliford. At the same time the greater part of the Brick-earth is older than the lower terrace, as is clearly seen in the sections at Grays, and in that at Crayford described by Mr. Spurrell.* Like the European Löss the brickearths may be distinguished as stratified and unstratified. The former type consists of finely bedded sands and loams, and contains a fresh-water fauna, which indicates a temperate climate. It is due to the overflow of the river, but the floods resembled those which take place at the present day rather than the tumultuous waters of an ice age. The other type of brickearth is an unstratified red loam, which owes its origin to the break up of the land surface by subaerial agencies and the redistribution of the loose material partly by wind and partly by the wash of rain-water on the valley slopes. These two types of brickearth are not separated in point of time, but probably alternate with one another. There were several breaks in the continuity of their formation, as is shown by the occurrence of land surfaces with palæolithic "workshops," but the stratigraphical significance of these breaks has not been clearly made out. The unstratified type of brickearth is very widely distributed in the Thames valley, though in many places it is a very thin deposit. It has been observed from the lowest levels near the river up to the tops of the highest terraces, and the greater part of the brickearth which is shown on the map is of this type.

After the formation of the main mass of the brick-earth, a third terrace of gravel was deposited which is lower and less extensive than either of the other two. During the interval between the epochs of the middle and lower terraces the Thames had quitted its course on the north side of the Purfleet Chalk and flowed in its present channel on the south side. No terrace gravel of the third stage occurs in the old channel. In Essex the London Clay can be traced in the tributary streams underneath the low terrace gravel at a level of about ten feet above ordnance datum. The surface gradually rises as it is traced northwards away from the river. Under the waterworks east of Walton the level is about the same. At Richmond it is rather less. Higher up the valley the low terrace rises with the river itself, though not to the same extent, and approaches the level of the middle terrace. The two are clearly separated from Isleworth through the village of Hampton as far as Hanworth Park, the London Clay forming a sharp feature all the way and cropping out at the surface here and there. But beyond Hanworth the boundary can only be traced at the surface by a slight inclination of the ground. The London Clay feature, however, seems to be continued underground, as it is found under the new reservoirs at Staines, four miles west of Hanworth. At the margin of the lower terrace the gravel often passes up the slopes in an attenuated bed which overlies and cuts into the brickearth resting on the middle terrace. In

* *Quart Journ. Geol. Soc.*, vol. xxxvi, p. 544.

some places it exhibits the phenomenon described as " trail " by the Rev. O. Fisher. A section at West Bedfont, in Middlesex, showed two feet of gravel overlying about three feet of loam, under which were twelve feet of gravel with sandy beds. It is well seen in the sections at Grays, and has been described by Mr. Spurrell (*op. cit.*) at Crayford in Kent. In Middlesex this gravel appears to be of very general occurence, is of considerable thickness, and is found at all levels to the top of the highest terrace. It is often associated with much disturbance of the underlying beds, suggestive of ice pressure, and has even been correlated with the Boulder Clay by some observers. Though it is of much later date than that deposit, yet it seems to afford evidence of a climate of some severity following the temperate conditions under which the brickearth was formed. Much of this unstratified gravel may have been formed in the way suggested by Mr. C. Reid,* viz., by the wash of rains over a frozen soil. This view seems to be confirmed by the association of the unstratified gravel on the valley slopes with a stratified gravel at a lower level, which was most probably due to torrential floods of the river.

In this connection it may be observed that on the top of the Chalk at Grays there is a bed of flints and chalk fragments a few feet thick which shows signs of disturbance by pressure. Mr. H. B. Woodward, who examined the deposit, thought that while it bears some resemblance to the Coombe Rock of Sussex, which Mr. Reid regards as indicating a recurrence to arctic conditions after an interglacial episode, yet the bed might possibly be due to glaciation of the surface at the time when the Chalky Boulder-clay was formed. Its age at Grays is uncertain, but its position suggests that it is later than the denudation of the high terrace gravel. It is not improbable that it is contemporaneous with the low terrace gravel and with the Coombe Rock.

During the formation of the lower terrace the river flowed in a descending course nearly as far as the present limit of tides, but for the next thirty miles its level was the same; so that the sea level probably stood somewhat higher than at the present day. The coast section at Clacton seems to throw light on this point and may be mentioned here.† At the base of the cliff mammalian bones of the same species as those of the Thames brickearth were found in association with fresh-water shells. Higher up were beds containing marine and fresh-water shells, alternating with beds of peat, and at the top a ten foot bed of gravel. Hence there was an oscillation of sea level followed by the formation of gravel, which seems also to have been the case at Grays, the purely freshwater strata of that place being the equivalents of fluviomarine strata near the open sea.

The next and last deposits of the Thames valley are the alluvia of the marshes. It might be inferred from an examination of these deposits in Middlesex that they followed closely

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* *Quart. Journ. Geol. Soc.*, vol. xlviii., p. 344.

† See W. H. Dalton, Geology of Colchester, *Mem. Geol. Survey*; and J. Brown, *Quart. Journ. Geol. Soc.*, vol. i., p. 341.

on the formation of the low terrace gravel. Scarcely any denudation has taken place between them. But in reality the gravel is of much older date, and the interval is probably longer than that which separates any of the deposits hitherto described. Mr. Spurrell has shown* that a still later gravel, from ten to twenty feet thick, underlies the alluvium from Richmond to Tilbury. Its base is nearly at Ordnance datum at the former place, but it descends between 60 and 70 feet at the latter. Hence, after the deposition of the low terrace gravel, the Thames must have been an inland river 30 miles further east than at present, and the land must have been 60 or 70 feet higher at the least. How much more it is impossible to say. Eventually, however, the land began to subside and the alluvium with its intercalated beds of peat records the gradual encroachment of the sea to its present limit.

The alluvium in Middlesex is usually very thin. There is a broad expanse by the Colne and its associated streams, but it is often merely a peaty covering of the river gravel. At one spot, however, near Wraysbury, at the works of the Staines Reservoir, a narrow channel was found which had been cut through the gravel to the London clay underneath and filled up with alluvium. The alluvium yielded the skull of the Elk or Moose (*Alces machlis*), and remains of fallow deer, red deer, horse, and pig, which have been described by Mr. E. T. Newton.† The channel seems to have been an old course of the Wraysbury river from which it has been artificially diverted.

Teeth of Mammoth, tichorine Rhinoceros, and Horse were found in the low level gravel but probably they were not in place.

Note.—Besides the authors quoted above, reference has been made to the published work of Messrs. M. A. C. Hinton, A. S. Kennard, H. W. Monckton, T. Belt, J. G. Goodchild, J. Allen Brown, Prof. W. B. Dawkins and Prof. J. Geikie, where opinions have been put forward on some points similar to those here given.

IX. Note on the Palæolithic Gravel of Savernake Forest, Wiltshire.‡

BY CLEMENT REID, F.R.S.

Knowle gravel-pit, from which so many Palæolitic implements have lately been obtained,§ lies on the east side of Savernake Forest, three miles N.N.E. of Savernake station, and just above the Marlborough and Hungerford Road. Its height is 450 feet above the sea; but only 40 feet above the bottom of the adjoining valley, which is a coombe in the porous Upper Chalk, dry at all times of the year, and apparently now never liable to floods. The water-level in the well at the cottage in the valley-bottom just below the pit is about forty feet below the

* *Proc. Geol Assoc.*, vol. xi., p. 89.

† *Quart. Journ. Geol. Soc.*, vol. lix., p. 80.

‡ Printed also in *Man* for April, 1903.

§ See Dr. Edgar Willett, on a collection of Palæolithic Implements from Savernake, *Journ. Anthrop. Inst.*, vol. xxxi., p. 310, 1901.

surface, and is said only to vary slightly according to the season. Small lateral valleys run from south to north and have almost isolated the ridge on which Knowle Farm stands.

The palæolithic gravel, however, does not occupy the highest part of the ridge, which a mile south of the farm rises to 550 feet and is capped by the Eocene strata. This higher land spreads westward, and separates the dry coombe from the valley in which the Great Western Railway and the Canal now run. A still higher ridge (about 600 feet) separates the dry coombe from the Kennet valley on the north.

It seems clear, therefore, that the palæolithic gravel of Knowle is connected with the dry valley now occupied by the Marlborough and Hungerford road. The gravel lies fully 100 feet below the divides on the north and south, and is only 40 feet above the bottom of this valley; most of this forty feet seems, however, to have been excavated since the gravel was deposited.

The gravel does not occupy any well-defined terrace, and its character does not suggest ordinary river-action; it suggests rather intermittent floods washing angular material from the slopes above.

The deposit seen in Knowle pit consists of 12 or 15 feet of unstratified gravel of unworn or shattered flints, with 10 or 15% of Tertiary pebbles, rare greywethers, and numerous Palæolithic implements, which occur at all levels, though most abundantly towards the base. There are no seams of clean washed sand or gravel. The stones are embedded in a loamy ferruginous matrix, which has been so thoroughly decalcified by percolating water that it seems hopeless to expect fossils, unless some massive specimen, such as a tooth of an elephant, may have resisted decay. The removal of the Chalk-rubble which once evidently formed a considerable proportion of the gravel, helps to account for the entire obliteration of any bedding that may have existed. Even now the irregular solution of the solid chalk below is tending still more to mix the material, for the workmen recently broke into a small cave, caused by the subsidence of the lower part of the gravel into a pipe in the chalk, while the surface remained undisturbed.

The exact limits of the Palæolithic deposit are impossible to make out in so wooded a country and in the absence of sections. It apparently occupies irregular shallow channels in a shelf roughly parallel with the valley below, for at the same level as the Knowle pit, in a field nearly half a mile to the east, I picked up another Palæolithic implement.

The relation of this Palæolithic gravel to the erosion of the valleys seems to show that it is contemporaneous with the well-known deposits of Southampton Water, Bournemouth and the Avon Valley. There is nothing to suggest a more ancient date; but at the same time the gravel seems more ancient than the erosion of the lower part of the dry chalk-valley below, and

more ancient than such deposits as the Coombe Rock of Brighton, or the lowest terrace gravels in the valleys of the south of England.

The reason for the occurrence of such large numbers of Palæolithic implements at certain points is not quite clear. I would suggest, however, that the sites of the camping grounds in a waterless and bare region of Chalk-downs would be determined by the occurrence of water-holes. In the case of the Knowle Farm locality the proximity of an outlier of clayey Tertiary strata probably gave the water, shelter, and firewood so essential to a race of hunters.

At present little is known as to the climatic conditions under which Palæolithic man existed in Britain; for though various slight indications suggest climatic extremes—with sharp alternations of cold drought and sudden floods—very few sedentary animals and plants have yet been collected in the same deposits. Pleistocene fossils have mostly been collected in other strata than those yielding the implements. To settle this question we need remains of plants or mollusca, for migrating mammals may leave a particular area for one half of the year only to return when a long period of drought or cold is over. This same enforced migration would compel Palæolithic man to follow the game, and would prevent permanent settlements except at favourable spots where water, shelter, and game could be found all the year round. In this connection it should not be forgotten that only as far away as Calais and Belgium the Palæolithic implements occur in true dust deposits, which graduate into the loess of the Rhine Valley, and suggest desert conditions approximating to those of Central Asia. In Britain the climate seems to have been milder; but still we have indications of drought in some of the mollusca and small mammals, and perhaps also in the extreme poverty of the flora.

X. The Fossil Plants from the Canonbie Coal Field.

BY ROBERT KIDSTON, F.R.S.

The revision of the Scottish Coalfields furnished an opportunity for the re-examination of the Canonbie Coalfield during last season, with the view of obtaining a collection of plants for the purpose of zonal classification. When the Canonbie Coalfield was originally mapped by the Geological Survey in 1876–7, considerable stratigraphical difficulties were experienced in determining the sequence and correlation of the strata. Eventually the view was adopted that the coalfield belonged probably to the horizon of the Calciferous Sandstone Series of Scotland. After the ground was surveyed, Mr. Macconochie collected in 1879 a large suite of fossils from various horizons in that district including plants from the Canonbie Coalfield. The latter indicated that the beds containing them belonged to the true Coal Measures. When collecting in the Canonbie area Mr.

Macconochie incidentally found plants in certain red shales near the border which suggested that the red shales and sandstones might be the representatives of the Upper Coal Measures of England.*

The examination of the plants collected during last season by Mr. Macconochie and myself, proves (1) that the Rowanburn coal seams belong to the Lower Coal Measures of England and Scotland, (2) that the coal seams formerly wrought in the Byre Burn represent the Middle Coal Measures, (3) that some at least of the red sandstones and shales lying between the Canonbie Coalfield and the Triassic rocks are on the horizon of the Upper Coal Measures.

LOWER COAL MEASURES.

The coals at present worked at Rowanburn belong to this series. Mr. Kenneth Bowie showed us a few specimens from Blinkbonny and Engine Pit of the Canonbie Colliery, and additional specimens were collected by ourselves.

The following species have been observed:—

(*a*) Blinkbonny Pit, Rowanburn.

Roof of Main Coal.—

cf. *Sphenopteris* (*Renaultia*) *Schutzei* Stur. sp.
Eremopteris artemisiaefolia, Sternb. sp.
Mariopteris muricata, Schl. sp.
Alethopteris lonchitica, Schl. sp.
Neuropteris heterophylla, Brongt.
" *gigantea*, Sternb.
" *Blissi*. Lesqx.
Calamites Cistii, Brongt.
Lepidodendron aculeatum, Sternb.
Cordaianthus Pitcairniae, L. & H. sp.

From Blaes above nine Feet coal:—

Calamites undulatus. Sternb.

(*b*) Engine Pit, Rowanburn:—

From shales associated with five foot Coal.

cf. *Sphenopteris obtusiloba*, Brongt.
Mariopteris muricata, Schl. sp.
Alethopteris lonchitica, Schl. sp.
Neuropteris heterophylla, Brongt.
" *gigantea*, Sternb.
" *obliqua*, Brongt. sp.
" *Blissi*, Lesqx.
Calamites, sp.
Lepidodendron obovatum, Sternb.
Lepidostrobus, sp.
Stigmaria ficoides, Sternb. sp.
Sphenophyllum cuneifolium, Sternb. sp.

From floor of seven Foot seam.—

Stigmaria ficoides, Sternb. sp.

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*The first public reference to the red shales and sandstones east of Canonbie, yielding plants resembling those of Upper Coal Measure age in England, was made in 1893 (Presidential address by R. Kidston, *Roy. Phys. Soc., Edinb.* 1893–4).

The following table shows the vertical distribution of these species:—

	U.C.M.	M.C.M.	L.C.M.
cf. *Sphenopteris obtusiloba*, Brongt.		x	x
cf. *Sphen.* (*Renaultia*) *Schutzei*, Stur. sp.		?	x
Eremopteris artemisiæfolia, Sternb. sp.		x	x
Mariopteris muricata, Schl. sp.	x	x	x
Alethopteris lonchitica, Schl. sp.	x	x	x
Neuropteris heterophylla, Brongt.		x	x
„ *gigantea*, Sternb.		x	x
„ *Blissi*, Lesqx.			x
„ *obliqua*, Brongt.		x	x
Calamites Cistii, Brongt.	x	x	x
„ *undulatus*, Sternb.	x	x	x
Lepidodendron aculeatum, Sternb.	x	x	x
„ *obovatum*, Sternb.		x	x
Stigmaria ficoides, Sternb. sp.	x	x	x
Sphenophyllum cuneifolium, Sternb. sp.		x	x
Cordaianthus Pitcairniæ, L. & H. sp.		x	x

Of the sixteen species under consideration, all occur in the Lower Coal Measures; fourteen occur in the Middle Coal Measures, excluding one of whose occurrence in that horizon there is some doubt, and six are common to all the divisions of the Coal Measures. In all cases, the majority of Lower Coal Measure species occur in the Middle Coal Measures, but the Middle Coal Measures are distinguished from the Lower Coal Measures by the presence of species peculiar to that division, and these are entirely absent from the Canonbie Coals which contain a most typical Lower Coal Measure flora.

From the Upper Coal Measures the Rowanburn Coals are easily distinguished from the entire absence of characteristic Upper Coal Measure plants. There is, therefore, no doubt as to the Rowanburn Coals belonging to the Lower Coal Measures.

MIDDLE COAL MEASURES.

The Middle Coal Measures appear in the Byre Burn a short distance above the Railway Viaduct near Gilnockie Station and extend as a narrow strip down each side of Byre Burn to its junction with the River Esk, where they cross the Esk and appear on both sides of the river for a short distance below Byreburnfoot. They are cut off to the north-west by a fault which throws them against the Carboniferous Limestone series a few yards above Byreburnfoot Bridge. On the Esk, a short distance below Byreburnfoot, the grey shales of the Middle Coal Measures gradually become stained red, and are succeeded by "Red Shales" and sandstones which are shown on both sides of the Esk till the newer Red Rocks (Trias) come in at Woodhouse, as shown in the published one-inch Sheet 11, a short distance below Canonbie Bridge. The horizon of the "Red Shales" will be referred to presently.

In the Middle Coal Measures several localities were found by Mr. Macconochie which yielded fossil plants, and one bed, passing across the mouth of Byre Burn a few yards above

Byre Burn Bridge and which is again found on the Esk about 30 yards below the junction of Byre Burn with the river, was particularly rich in species of fossil plants.

A list of the species from the different localities in the Byre Burn Series, may now be given.

(*a*) Dark Shale bed in stream a few yards above Bridge at foot of Byre Burn, Canonbie. Horizon. Band lying between ¾ Coal and Main Coal.

Sphenopteris mixta, Schimper.
Alethopteris lonchitica, Schl. sp.
„ *Davreuxi*, Brongt. sp.
„ *Grandini*, Brongt. sp.
Calamocladus equisetiformis, Schl. sp.
Calamostachys typica, Schimper (*pars*).
Sigillaria elegans, Sternb. sp.
Spenophyllum cuneifolium, Sternb. sp.
„ „ *var. saxifragæfolium*, Sternb.
Cordaites principalis, Germar. sp.
Cordaianthus cf. Pitcairniæ, L. & H. sp.
Cordaicarpus Cordai, Geinitz. sp.

(*b*) Dark shale bed with ironstone band, River Esk, left bank, about 30 yards below junction of Byre Burn, and a short distance above Old Engine House. Horizon. Band lying between ¾ Coal and Main Coal.

Sphenopteris Laurenti, Andrae.
Alethopteris Davreuxi, Brongt. sp.
„ *Grandini*, Brongt. sp.
Pecopteris, sp.
Calamites (Calamitina) undulatus, Brongt. sp.
„ („) *Schutzei*, Stur.
„ („) *pauciramis*, Weiss.
„ („) sp.
„ *(Eucalamites) ramosus*, Artis.
„ *(Stylocalamites) Suckowii*, Brongt.
„ („) *Cistii*, Brongt.
Calamocladus equisetiformis, Schl. sp.
„ *charaeformis*, Sternb. sp.
Calamostachys typica, Schimper (*pars*).
cf. *Paracalamostachys Williamsoniana*, Weiss.
Annularia radiata, Brongt.
Sigillaria elegans, Sternb. sp.
Pinakodendron Macconochiei, n. sp. *
Stigmaria ficoides, Sternb. sp.
„ „ var.
Sphenophyllum cuneifolium, Sternb. sp.
Cordaites principalis, Germar sp.
Cordaianthus Volkmanni, Ett. sp.
Cordaianthus, sp.
Carpolithes, sp.
Sternbergia, sp.

(*c*) Byre Burn, about 300 yards above junction with River Esk. In soft grey shale.

Neuropteris gigantea, Sternb.

(*d*) River Esk, left bank, about 240 yards below junction of Byre Burn. In soft stained shale.

Neuropteris gigantea, Sternb.
Lepidodendron, cf. lycopodioides, Sternb.

* See paper read before *Roy. Soc., Edinb.*

(*e*) Byre Burn, underneath Railway Viaduct, near Gilnockie Station, Canonbie. In clayey sandy shale.

Sphenopteris obtusiloba, Brongt.
„ *multifida*, L. & H.
Mariopteris muricata, Schl. sp.
Alethopteris lonchitica, Schl. sp.

The specimens from this locality were collected by Mr Macconochie in 1879.

Localities (*a*) and (*b*) are different portions of the same band, which lies between the ¾ Coal and Main Coal of Byre Burn. The rarity of *Sigillaria* and absence of *Lepidodendron* in this zone is rather remarkable, as *Stigmaria* was very abundant.

Locality (*c*) holds a somewhat lower horizon in the series than localities (*a*) and (*b*); locality (*d*) is a little higher in the series than (*a*) and (*b*), while locality (*e*), the original locality from which plants were collected in Byre Burn, is the lowest horizon from which we have got plants from Byre Burn.

As all these localities are situated on the Byre Burn Coal Series, the species derived from them may be placed in one table, with the object of comparing the flora with that of the three divisions of the Coal Measures.

Fossil Plants from Byre Burn Coal Series.

	U.C.M.	M.C.M.	L.C.M.
Sphenopteris obtusiloba, Brongt.		x	x
„ *Laurenti*, Andrae.		x	x
„ *mixta*, Schimper.		x	
„ *multifida*, L. & H.		x	
Pecopteris, sp.			
Mariopteris muricata, Schl. sp.	x	x	x
Alethopteris lonchitica, Schl. sp.	x	x	x
„ *Davreuxi*, Brongt. sp.	x	x	
„ *Grandini*, Brongt. sp.	x		
Neuropteris gigantea, Sternb.		x	x
Calamites undulatus, Sternb.	x	x	x
„ *Schützei*, Stur.		x	x
„ *pauciramis*, Weiss.		*	
„ *ramosus*, Artis.	x	x	x
„ *Suckowi*, Brongt.	x	x	x
„ *Cistii*, Brongt.	x	x	x
Calamocladus equisetiformis, Schl. sp.	x	x	x
„ *charaeformis*, Sternb. sp.		x	
Calamostachys typica, Schimper (*pars*)		x	x
cf. Paracalamostachys Williamsoniana, Weiss.			x
Annularia radiata, Brongt.		x	x
Lepidodendron, cf. *lycopodioides*, Sternb.		x	x
Sigillaria elegans, Sternb. sp.		x	x
Pinakodendron Macconochiei, n. sp.		*	
Stigmaria ficoides, Sternb. sp.	x	x	x
Sphenophyllum cuneifolium, Sternb. sp.		x	x
„ „ var. *saxifragaefolium*, Sternb.		x	x
Cordaites principalis, Germar. sp.		x	x
Cordianthus, cf. *pitcairniæ*, L. & H. sp.		x	x
„ *Volkmanni*, Ett. sp.		x	
Cordaicarpus Cordai, Geinitz. sp.		x	
Carpolithus, sp.			
Sternbergia, sp.			

* These are the first British records for these fossils, but their horizon on the continent seems to agree with our Middle Coal Measures.

Of the Byre Burn fossil plants a few extend into th Coal Measures but these belong to those species w common to all three divisions of the Coal Measures, exception of *Alethopteris Davreuxi*, Brongt. sp., whic only in the Upper and Middle Coal Measures. A number of the Byre Burn plants appear in the Lo Measures, but after deducting these, there are several le are peculiar to the Middle Coal Measures as far as we a know. These are *Sphenopteris mixta*, Schimper, *Sph multifida*, L. and H., *Calamites pauciramis*, Weiss, *Cala charæformis*, Sternb. sp., *Pinakodendron Macconochi Cordaianthus Volkmanni*, Ett. sp., and *Cordaicarpus* Geinitz, sp. *Alethopteris Grandini*, Brongt. sp. which is plentiful at localities (*a*) and (*b*) has not previous met with out of the Upper Coal Measures, and though teris *Laurenti*, Andrae and *Sigillaria elegans*, Sternb. occur in the Lower Coal Measures, they are very rare horizon, being much more characteristic of the Mid Measures.

From the evidence afforded by these fossils, I have n tion in classing the Byre Burn beds with the Mid Measures of England.

UPPER COAL MEASURES ("THE RED SHALES").

These occupy a considerable tract of ground and exposed in many places in the Parish of Canonbie an neighbouring part of Cumberland.

They are shown in the Rowanburn where they are against the Lower Coal Measures at the Engine Pit. T runs almost east and west, and they are again seen faulte the Carboniferous Limestone Series a very short distan Blae Pot, on the Liddel Water, a little south of Pento From this line they extend southwards into Cumberlan ing the newer Red Rocks (Trias) in the west, a short west of Riddings Junction.

Reference has already been made to their occurrenc River Esk, where they succeed the Middle Coal Mea short distance below Byre Burnfoot, from which point be traced to Woodhouse, about a quarter of a mil Canonbie Bridge.

The series, as a whole, is extremely barren of fossils, it offers many good sections along the River Esk and th Water, and though these sections were more or less examined by Mr. Macconochie and myself, they did no single fossil plant.

At Jockie's Syke in Cumberland, 1 mile east by Riddings Junction, where, in 1879 Mr. Macconochie few small specimens, we were more successful, and di plant remains in three different bands.

The section exhibited here is, however, high up in t and for this portion of it, the fossils indicate an Upp Measure age.

It is very unfortunate that the lower portion of the series along the River Esk is so barren (though plants may still be found in it, for the extent of ground to examine is considerable and our time was limited), for if the rocks form a continuous series with the Byre Burn Middle Coal Measures (though there may possibly be a fault between them), one would expect to find in the lower portion of the "Red Shales," a transition flora, composed partly of Middle and partly of Upper Coal plants, similar to the series which occurs above the Middle Coal Measures in the Potteries Coal Field, and which I have named the Upper Transition Series.* From the absence of any plant remains in the lower beds of the red shales on the Esk, I am unable to determine whether they belong to this Upper Transition Series or to the Upper Coal Measures.

The flora of the upper beds, however, as developed in Jockie's Syke, have a distinct Upper Coal Measure facies, and though one misses from the list of plants collected such typical names as *Pecopteris arborescens* and its allies, several of the *Cyatheites Pecopterids* occur, but the preservation of the specimens was so unsatisfactory, that it was impossible to determine them specifically. In outline, one agrees perfectly with *Pec. arborescens*, Schloth sp., but in absence of the nervation, a satisfactory determination of the *Cyatheites Pecopterids* cannot be made. In most of the other ferns the nervation was well seen.

Of course it is difficult sometimes to draw the exact line between the Upper Transition Series and the Upper Coal Measures, for they are only the upper and lower end of a continuous chain, but taking all the available evidence into consideration, I think we must class the "Red Shales" of Jockie's Syke with the Upper Coal Measures.

The following species were collected from the "Red Shales" at Jockie's Syke, 1 mile east by north of Riddings Junction, Cumberland :—

Locality (a) Streamlet entering on right of main stream, 30 yards south of North British Railway. In soft red and greenish shales.

Pecopteris (Cyatheites).
(Two species at least).
Alethopteris Serlii, Brongt. sp.
„ *Grandini*, Brongt. sp.
„ *aquilina*, Schl. sp.
Neuropteris ovata, Hoffm.
„ *flexuosa*, Sternb.
„ *Scheuchzeri*, Hoffm.
Calamites undulatus, Sternb.
Calamitina, sp.
Calamocladus equisetiformis, Schl. sp.
Annularia radiata, Brongt.
Annularia stellata, Schl. sp.
Lepidodendron fusiforme, Corda, sp.
Lepidophyllum, sp.

* Kidston, "On the various divisions of British Carboniferous Rocks as determined by their Fossil Flora," *Proc. Roy. Phys. Soc. Edin.*, vol. xii., p. 228–229, 1894; also "Additional Records and Notes on the Fossil Flora of the Potteries Coal Field, North Staffordshire," *Trans. North Staffordshire Field Club*, 1897. Stoke on Trent.

Locality (b) Main Stream (Jockie's Syke) about 125 yards above Railway. In purplish shale.

Alethopteris aquilina, Schl. sp.
„ *Serlii*, Brongt. sp.
Neuropteris flexuosa, Sternb.
Stigmaria ficoides, Sternb. sp.

Locality (c) main stream of Syke, about 300 yards above the railway. In purplish clayey shales.

Pecopteris (*Cyatheites*).
Alethopteris, sp.
Neuropteris flexuosa, Sternb.
„ *Scheuchzeri*, Hoffm.

The vertical distribution of these fossils is seen in the following table.

	U.C.M.	M.C.M.	L.C.M.
Pecopteris (*Cyatheites*), species	x		
Alethopteris aquilina, Schl. sp.	x	x	
„ *Grandini*, Brongt. sp.	x	x	
„ *Serlii*, Brongt. sp.	x		
Neuropteris ovata, Hoffm.	x		
„ *flexuosa*, Sternb.	x		
„ *Scheuchzeri*, Hoffm.	x	x	
Calamites undulatus, Sternb.	x	x	x
Calamitina, sp.			
Calamocladus equisetiformis, Schl. sp.	x	x	x
Annularia radiata, Brongt.	x	x	x
„ *stellata*, Schl. sp.	x		
Lepidodendron fusiforme, Corda sp.			x
Lepidophyllum, sp.			
Stigmaria ficoides, Sternb. sp.	x	x	x

An analysis of the fossil plants found at Jockie's Syke shows that of the 13 names available for comparison, 12 occur in the Upper Coal Measures, and of these 5 are peculiar to that horizon, 7 are common to Upper and Middle Coal Measures, and 5 also occur in the Lower Coal Measures, but of these 5, 4 are common to all the divisions of the Coal Measures, while the 5th, *Lepidodendron fusiforme*, Corda sp. I have only seen previously in the Lower Coal Measures.

This analysis shows that at least the upper portion of the "Red Shales" must be classed with the Upper Coal Measures, for owing to the entire absence of a single characteristic Middle Coal Measure Species, it seems impossible to regard these beds as belonging to the Upper Transition Series.

The fact of *Lepidodendron fusiforme*, Corda sp. occurring in the Upper Coal Measures, which has hitherto only been discovered in the Lower Coal Measures (where, however, it is extremely rare), does not vitiate the conclusion arrived at in regard to the age of these "Red Shales," but merely shows that *Lepidodendron fusiforme* is one of those species which extends throughout the whole of the Coal Measures. It is also the only plant discovered at Jockie's Syke, which had not previously been found in the Upper Coal Measures of other areas.

APPENDIX XI.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH GASTEROPODA and SCAPHOPODA from the RHÆTIC BEDS, LIAS, and INFERIOR OOLITE, preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

BY H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain: these are marked [**Doubtful**]. The figures in brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed:—

Ann. Mag. Nat. Hist.: Annals and Magazine of Natural History, London.

"Cotteswold Hills": "The Cotteswold Hills Hand-book," by J. Lycett, London.

Geol. Mag.: The Geological Magazine, London.

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London. (The dates quoted refer to year of *issue* only).

Proc. Cotteswold Nat.: Proceedings of the Cotteswold Naturalists' Club, London.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Rep. Belfast Nat. App. 1: Seventh Annual Report of the Belfast Naturalists' Field Club, Appendix 1, Belfast.

"Yorkshire Lias": "The Yorkshire Lias," by R. Tate & J. F. Blake, London.

RHÆTIC.

Natica pylensis, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1865, pl. iv., f. 10, p. 89.
Rhætic (*Avic. contorta* zone). [7827] Pyle, Glamorganshire.

LIAS.

Actæonina chrysalis, Tate. **T**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 23, p. 356.
Middle Lias (*A. spinatus* zone). [8463] Eston.

Actæonina ilminsterensis, Moore.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 7, p. 355.
Middle Lias. [8462] Cleveland.

Cerithium acriculum, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 1, p. 351.
Middle Lias (*A. spinatus* zone). [7967] Hawsker.

Cerithium Dayii, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 7.
Middle Lias. [7966] Down Cliff, Charmouth

Cerithium ibex, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 8, p. 405.
Lower Lias (*A. Jamesoni* zone). [7960] Cheltenham.

Cerithium liassicum, Moore.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 18, p. 351.
Middle Lias (*A. spinatus* zone). [7968] Eston.

Cerithium ligaturalis, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 7.
Lower Lias. [7961] Redmile, Lincolnshire.

Cerithium Slatteri, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 7, p. 406.
Lower Lias (*A. Jamesoni* zone). [7963] Cheltenham.

Cerithium subfistulosa, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Lower Lias. [7964] Redmile, Lincolnshire.

Cerithium tenuicostatum (Portlock).
R. Tate, Rep. Belfast, Nat., Appendix 1, 1870, pl. 1, f. 8, p. 15.
Lower Lias. [7965] Ballintoy.

Chemnitzia acula, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 10, p. 354.
Upper Lias (*A. annulatus* zone). [7988] Glaizedale.

Chemnitzia citharella, Tate. **T.**
R. Tate. "Yorkshire Lias," 1876, pl. x., f. 4, p. 354.
Middle Lias (*A. margaritatus* zone). [7991] Staithes.

Chemnitzia complicata, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Middle Lias (Marlstone). [7992] Hyde near Yeovil.

Chemnitzia nuda (Muenster).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 9, p. 354.
Middle Lias (*A. margaritatus* zone). [7993] Huntcliff.

Chemnitzia punctata, Tate. **T.**
R. Tate, Rep. Belfast, Nat., App. 1, 1870, pl. i., f. 11, p. 15.
Lower Lias (*A. angulatus* zone). [7989] Island Magee.

Chemnitzia semitecta, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 23, p. 353.
Middle Lias (*A. margaritatus* zone). [8461] Staithes.

Chemnitzia trivia, Tate. **T.**
R. Tate, Geol. Mag., vol. viii, 1871, p. 8.
Lower Lias. [7990] Bridgend.

Cryptænia Brycei, Tate.
R. Tate, Rep. Belfast Nat., App. I., 1870, pl. i, f. 13, p. 16.
Lower Lias (*A. angulatus* zone). [7936] Garron Point, Antrim.

Dentalium elongatum, Muenster.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 28, p. 332.
Middle Lias (*A. spinatus* zone). [7997] Kettleness.

Dentalium etalense, Terquem and Piette.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 13, p. 332.
Lower Lias (*A. angulatus* zone). [7998] Redcar.

Dentalium giganteum, Phillips.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 10, p. 331.
Lower Lias. [8000] Hawsker Cliff.

Dentalium limatulum, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 18, p. 332.
Lower Lias. [8001] Redcar.

Dentalium Portlocki, Tate. T.
R. Tate, Rep. Belfast Nat., App. 1., 1870, pl. i., f. 15, p. 17.
Lower Lias (*A. angulatus* zone). [7999] Island Magee.

Discohelix aratus, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 5, 5*a*, p. 340. (See also *Straparolus*.)
Middle Lias (*A. margaritatus* zone). [7977] Staithes.

Discohelix Oppeli (Martin).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 8*a*, *b*, p. 340.
Lower Lias (*A. Bucklandi* zone). [7982] Redcar.

Discohelix semiclausus, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 14, p. 341.
Lower Lias (*A. angulatus* zone). [7980] Redcar.

Discohelix striatus (Piette).
R. Tate, "Yorkshire Lias," 1876, pl. ix., figs. 8, 9, p. 340.
Lower Lias (*A. Bucklandi* zone) [7983] Redcar.

Eucyclus acuminatus (Chapuis and Dewalque).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 20, p. 346.
Lower Lias (*A. angulatus* zone). [7957] Redcar.

Eucyclus cingendus, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl., x., f. 15, p. 348.
Middle Lias. [7958] Eston.

Eucyclus conspersus, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 11*a*, *b*, p. 347.
Middle Lias. [7959] Eston.

Eucyclus selectus (Chapuis and Dewalque).
R. Tate, "Yorkshire Lias," 1876, p. 346.
Lower Lias (*A. Bucklandi* zone). [8473] Marske Bay.

Eucyclus undulatus (Phillips).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 12*a*, *b*, p. 347.
Middle Lias (*A. spinatus* zone). [8466] Upleatham.

Euomphalus minutus, Schuebler.
R. Tate, "Yorkshire Lias," 1876, p. 341. (See also *Natica pilula*).
Upper Lias. [8474] Scagdale.

Exelissa numismalis, Tate. T.
R. Tate, Ann. Mag. Nat. Hist., vol. iv., 1869, p. 417 ; Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 5, p. 403.
Lower Lias (*A. Jamesoni* zone). [7976] Cheltenham.

Hydrobia solidula (Dunker).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 6, p. 345.
Lower Lias (*A. oxynotus* zone). [7983] Robin Hood's Bay.

Littorina biornata, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 17, p. 404.
Lower Lias (*A. Jamesoni* zone). [7984] Charmouth.

Littorina clevelandica, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 17*a*, *b*, p. 348.
Middle Lias (*A. margaritatus* zone). [7985] Huntcliff.

Monodonta modesta, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Middle Lias (Marlstone). [8007] Churchdown, Cheltenham.

Natica pilula, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Upper Lias. (See also *Euomphalus minutus*). [7912] Dumbleton.

Natica purpuroidea, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 13, p. 349.
Lower Lias. [7996] Redcar.

Nerita alternans, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x, f. 16*a*–*c*, p. 333.
Middle Lias (*A. spinatus* zone). [8465] Upleatham.

Patella gratans, Tate. **T.**
R. Tate, Geol. Mag., vol. ii., 1875, p. 204.
Middle Lias (*A. spinatus* zone). [7969] Uley, Gloucestershire.

Patella suttonensis, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iv., f. 9, 9*a*, p. 88.
Lower Lias. [7945] Sutton.

Pitonillus sordidus, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 19*a*–*c*, p. 343.
Lower Lias (*A. Bucklandi* zone). [7986] Redcar.

Pleurotomaria concava, Martin.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 27, p. 339
Lower Lias (*A. Bucklandi* zone). [7932] Redcar.

Pleurotomaria helicinoides (Roemer).
R. Tate, "Yorkshire Lias," 1876, pl. x, f. 7*a*, *b*, p. 338.
Middle Lias (*A. spinatus* zone). [8464] Eston.

Pleurotomaria Hennocqui ? Terquem.
R. Tate, "Yorkshire Lias," 1876, p. 337.
Lower Lias. [8470] Marske Bay.

Pleurotomaria similis, J. Sowerby.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 4, p. 337.
Lower Lias (*A. Bucklandi* zone). [7931] Redcar.

Pleurotomaria tectaria, Tate. **T.**
R. Tate, Rep. Belfast Nat., App. I., 1870, p. 17.
Lower Lias (*A. angulatus* zone). [7933] Between Garron Point and Red Bay

Pleurotomaria tectaria, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 26, p. 338.
Lower Lias. [7934] Redcar.

Rissoa nana (Martin).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 17, p. 345.
Lower Lias (*A. Bucklandi* zone). [8468] Redcar.

Solarium inornatum, Tate. T.
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Middle Lias. [7987] Chipping Campden.

Solarium lucens, Tate. T.
R. Tate, Geol. Mag., vol. viii, 1871, p. 8.
Lower Lias (*A. Henleyi* zone). [7956] Mickleton.

Solarium Thomsoni, Tate. T.
R. Tate, Rep. Belfast Nat., App. I, 1870, pl. i., f. 9, p. 16.
Lower Lias (*A. angulatus* zone). [7954] Glenarm.

Straparolus aratus, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870. pl. xxvi., f. 21, p. 404. (See also *Discohelix*).
Lower Lias (*A. Jamesoni* zone). [7978] Charmouth.

Straparolus bellulus, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 22, p. 404.
Lower Lias (*A. Jamesoni* zone). [7979] Charmouth.

Straparolus wrightianus, Tate. T.
R. Tate. Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 23, p. 404.
Lower Lias (*A. Jamesoni* zone). [7981] Charmouth.

Tornatella capricorni, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 18, p. 405.
Lower Lias (*A. Jamesoni* zone). [7935]
Aston Magna, Gloucestershire.

Trochus inconstans, Tate. T
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Lower Lias. [7946] Bridgend, Glamorgan.

Trochus redcarensis, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 14*a–c*, p. 342.
Lower Lias (*A. Bucklandi* zone). [7947] Redcar.

Trochus Robigus, Tate. T
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 3*a*, *b*, p. 341.
Lower Lias (*A. oxynotus* zone). [7948] Robin Hood's Bay.

Trochus solitarius, Tate. T.
R. Tate, Q. J. G. S., vol. xxxi., 1875, p. 506, f. 2 (Text figure).
Lower Lias [7949] Munger.

Trochus Thetis, Muenster.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 4, p. 403; "Yorkshire Lias," 1876, p. 342.
Lower Lias (*A. Jamesoni* zone). [7950] Aston Magna.

Turbo aciculus (Stoliczka).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 22, p. 344.
Middle Lias (*A. spinatus* zone). [8002] Cleveland.

Turbo admirandus, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 10, p. 403.
Lower Lias (*A. Jamesoni* zone). [7951] Cheltenham.

Turbo cyclostoma, Benz.
R. Tate "Yorkshire Lias," 1876, pl. ix., f. 19, p. 344.
Middle Lias. [8003] Hawsker.

Turbo latilabrus (Stoliczka).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 15, p. 343.
Middle Lias (*A. spinatus* zone.) [8004] Eston.

Turbo lineatus, Moore.
R. Tate "Yorkshire Lias," 1876, pl. ix., f. 20, p. 343.
Middle Lias (Ironstone). [8005] Upleatham.

Turbo Philemon, d'Orbigny.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 25, p. 344.
Lower Lias. [7952] Redcar.

Turbo reticulatus, Moore.
R Tate, "Yorkshire Lias," 1876, p. 344.
Lower Lias (*A. Bucklandi* zone). [8471] Redcar.

Turbo solarium, Piette.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 16, p. 343.
Lower Lias (*A. Bucklandi* zone). [7953] Redcar.

Turbo Wilsoni, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 5*a*, *b*, p. 344.
Lower Lias (*A. Bucklandi* zone). [7955] Redcar.

Turritella Deshayesea, Terquem.
R. Tate, "Yorkshire Lias," 1876, p. 349.
Lower Lias (*A. Bucklandi* zone). [8467] Redcar.

Turritella Dunkeri, Terquem.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 3, p. 350.
Lower Lias (*A. oxynotus* zone). [8472] Robin Hood's Bay.

Turritella regularis (Terquem and Piette).
R. Tate, "Yorkshire Lias," 1876, p. 350.
Lower Lias (*A. oxynotus* zone). [8006] Robin Hood's Bay.

INFERIOR OOLITE.

Acteonina antiqua, Lycett. T.
J Lycett, "Cotteswold Hills," 1857, pl. iv., f. 9, p. 125.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 6, p. 477.
Inferior Oolite. [8015] Rodborough Hill.

Acteonina convoluta, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 8, p. 125. Re-figured as **Actæonina? convoluta** W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 7, p. 477.
Inferior Oolite. [8016] Rodborough Hill.

Actæonina gigantea (Deslongchamps) T.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 2, p. 475.
Inferior Oolite. [8017] Cotteswold Hills.

Acteonina ovata, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
W. H. Hudleston, Mon. Pal. Soc., 1896, p. 475.
Inferior Oolite. [8113] Nailsworth?

Alaria solida *vide* **Rostellaria.**

Alaria unicornis *vide* **Rostellaria.**

Amberleya biserta (Phillips).
W. H. Hudleston, Geol. Mag., 1884, pl. viii., f. 11*a–c*, p. 249; Mon. Pal. Soc., 1892, pl. xxiii., f. 2, p. 288.
Inferior Oolite (Dogger). [8039] Blue Wyke, Yorkshire.

Bulla Favrei, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 7, p. 125.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 10, p. 481.
Inferior Oolite. [8014] Avening, Minchinhampton.

Ceritella sculpta, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5364] Leckhampton.

Ceritella tumidula, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i, 1853, p. 80.
Inferior Oolite. [5365] Leckhampton.

Cerithinella Brodiei, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. xii., f. 4*a*, *b*, p. 187.
Inferior Oolite. [8044] Nailsworth.

Cerithium "cingula," Hudleston.
W. H. Hudleston, Mon Pal. Soc., 1889, pl. ix., f. 8, p. 162.
Inferior Oolite. [8045] Nailsworth.

Cerithium leckhamptonense, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. ix., f. 2, p. 157.
Inferior Oolite. [8047] Leckhampton Hill.

Cerithium (Colina) Lycetti, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 22*a*, *b*, p. 485.
Inferior Oolite. [8049] Nailsworth.

Cerithium turris, Hudleston. T.
W. H. Hudleston, Geol. Mag., 1884, pl. iii., f. 13, 13*a*, p. 61; Mon. Pal. Soc. 1889, pl. ix., f. 15, p. 166.
Inferior Oolite (Dogger). [8048] Blue Wyke

Cerithium sp. near to *C. variculosum*, Deslongchamps.
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. x., f. 1, p. 166.
Inferior Oolite. [8046] Rodborough Hill.

Chemnitzia elegans, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
Inferior Oolite. [5363] Leckhampton.

Chemnitzia gracilis, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, pl. xi., f. 3, p. 418; Proc. Cotteswold Nat., vol. i., 1853, pl. ii., f. 3, p. 79. Re-figured as **Nerinæa gracilis**: "Cotteswold Hills," 1857, pl. ii., f. 3, 3*a*, p. 124; and W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xii., f. 13*a*, *b*, p. 196.
Inferior Oolite. [8082, 8083] Nailsworth.

Chemnitzia procera, Deslongchamps.
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 1, p. 150.
Inferior Oolite. [8090] Nailsworth.

Cirrus Etheridgii, *vide* **Turbo.**

Cryptaulax scobina (Deslongchamps) *var.*
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. xi., f. 11, p. 181.
Inferior Oolite Sands. [7994] Nailsworth.

Cylindrites attenuatus, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
Inferior Oolite. [5361] Leckhampton.

Cylindrites cylindricus, Morris and Lycett, *var.*
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 16*a*, *b*, p. 481.
Inferior Oolite. [8018] Nailsworth?

Cylindrites mamillaris, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
Inferior Oolite. [5362] Leckhampton.

Cylindrites tabulatus, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79. Figured W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 14 *a*, *b*, p. 479.
Inferior Oolite. [8112] Nailsworth.

Cylindrites tabulatus, Lycett, *var* **weldonis**, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 13 *a*, *b*, p. 479.
Inferior Oolite. [8019] Weldon.

Delphinula quaterno-cingillata, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416; Proc. Cotteswold Nat., vol. i., 1853, p. 77.
Inferior Oolite. [8108] Nailsworth.

Delphinula (Turbo) santonis, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xxx., f. 18, 18 *a*, p. 369.
Inferior Oolite. [8037] Santon, Lincolnshire.

Emarginula alta, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416; Proc. Cotteswold Nat., vol. i., 1853, p. 77. Figured as **Rimula alta**: W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xli., f. 18 *a*, *b*, p. 455.
Inferior Oolite. [8024] Locality doubtful.

Emarginula granulata, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5329] Leckhampton.

Emarginula leckhamptonensis, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5333] Leckhampton.

Eulima parvula, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1853, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5371] Leckhampton.

Fissurella Brodiei, Lycett [**Doubtful**]. T.
J Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415 ; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5335] Leckhampton.

Fusus ? carino-crenatus, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 420 ; Proc. Cotteswold Nat., vol. i., 1853, p. 81. Figured as **Purpurina (Eucycloidea) carino-crenata**: W. H. Hudleston, Mon. Pal. Soc., 1888, pl. ii., f. 7 *a*, *b* p. 97.
Inferior Oolite. [8040] Locality doubtful.

Hamusina oppelensis, *vide* **Turbo.**

Malaptera Bentleyi, (Morris and Lycett).
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. iii., f. 1*a*, p. 101.
Inferior Oolite (Collyweston Slate). [8102] Collyweston.

Natica adducta, Phillips, *var.* **globata**, Hudleston.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 6, p. 259.
Inferior Oolite (Lower Trigonia-Grit). [8093] Cheltenham.

Natica adducta *var* **oppelensis**, *vide* **Natica oppelensis.**

Natica canaliculata, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417 ; Proc. Cotteswold Nat., vol. i., 1853, p. 78. Figured "Cotteswold Hills," 1857, pl. iii., f. 10, p. 155.
Inferior Oolite. [8092] Nailsworth.

Natica cincta ? Phillips.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 17, p. 259.
Inferior Oolite [8099] Cheltenham.

Natica hulliana, Lycett. T.
Morris & Lycett, Mon. Pal. Soc. Suppl., 1863, pl. xli., f. 2, p. 13.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 12, p. 262.
Inferior Oolite. [8042] Nailsworth.

Natica cf. **Michelini**, d'Archaic.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 18*a*, *b*, p. 269.
Inferior Oolite. [8091] Nailsworth.

Natica oppelensis, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. i., f. 4, p. 123. Refigured as **Natica adducta**, *var* **oppelensis**: W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 2, p. 258.
Inferior Oolite Sands. [8098] Nailsworth.

Nerinæa cotteswoldiæ, Lycett. T.
J. Lycett "Cotteswold Hills," 1857, pl. ii., f. 2 *a*, *b*, p. 124.
Inferior Oolite. [8085] Nailsworth.

Nerinæa gracilis, *vide* **Chemnitzia.**

Nerinæa Jonesii, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 4, p. 124. Refigured W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xv., f. 9 *a*, *b*, p. 218.
Inferior Oolite. [8089] Nailsworth.

Nerinæa oppelensis, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 6 *a*, *b*, p. 123.
Inferior Oolite. [8086] Selsley Hill.

Nerinæa pseudocylindrica, d'Orbigny.
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 5, p. 166.
Inferior Oolite. [8088] Nailsworth.

Nerinæa santonis, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xvi., f. 8 *b*, *c*, p. 224.
Inferior Oolite. [8087] Santon.

Nerinæa subcingenda, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xiv., f. 16 *a*, p. 212.
Inferior Oolite. [8084] Santon.

Nerita cassidiformis, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist. vol. vi., 1850, p. 416 ; Proc. Cotteswold Nat. vol. i, 1853, p. 77.
Inferior Oolite. [5342] Leckhampton.

Nerita minuta, Sowerby, *var.* **tumidula**, Phillips.
W. H. Hudleston, Geol. Mag., vol. i., 1884, pl. ix., f. 4 *a*, *b*, p. 296.
Inferior Oolite (Dogger). [8022] Blue Wyke, Scarborough.

Neritopsis (?Turbo) lævigata (Phillips) *var.* **A.**
W. H. Hudleston, Geol. Mag., vol. ii., 1885, pl. ii., f. 2, p. 49. Refigured as "**Neritopsis lævigata.**" W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xxviii., f. 10, p. 344.
Inferior Oolite (Dogger). [8023] Blue Wyke, Scarborough.

Patella cf. **cingulata**, Muenster.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xlii., f. 5 *a–c*, p. 461.
Inferior Oolite. [8420] Rollwright, Oxfordshire.

Patella nitida, Deslongchamps.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xlii, f. 7 *a*, *b*, p. 461.
Inferior Oolite. [8029] Leckhampton ?

Patella retifera, Lycett **[Doubtful]** **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415 ; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5327] Leckhampton.

"**Phasianella**" **elegans** (Morris and Lycett).
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xix., f. 11 *a*, p. 252.
Inferior Oolite (Lincolnshire Limestone). [4393] Locality doubtful.

Pleurotomaria Aglaia, d'Orb. *var.*
J. Morris in E. Hull, M.G.S., Cheltenham, 1857, pl. i., f. 7,7 *a-d*, p. 104.
Inferior Oolite (Pea-grit). [8020, 8021] Crickley Hill, Cheltenham.

Purpurina aperta, *vide* **Turbo elaboratus.**

Purpurina aspera, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. i., f. 11 *e*, p. 91.
Inferior Oolite. [8094] Bradford Abbas.

Purpurina carino-crenata, *vide* **Fusus ?**

Purpurina inflata, Tawney.
W. H. Hudleston, Mon. Pal. Soc., 1888, pl., ii., f. 2 *f*, p. 92.
Inferior Oolite [8096] Rodborough Hill.

Purpurina rotunda, Hudleston.
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. ii., f. 3 *d*, p. 93.
Inferior Oolite. [8095] Bradford Abbas.

Purpurina sp., *vide* **Turbo elaboratus.**

Rimula alta, *vide* **Emarginula.**

Rissoina obtusa, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi, 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5373] Leckhampton.

Rostellaria solida, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80. Figured as **Alaria solida**: W. H. Hudleston, Mon. Pal. Soc., 1889, pl. vii., f. 5, p. 139.
Inferior Oolite. [8080] Nailsworth.

Rostellaria spinigera, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80. Figured W. H. Hudleston, Mon. Pal. Soc., 1889, pl. vii., f. 4, p. 138.
Inferior Oolite. [8079] Nailsworth.

Rostellaria unicornis, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80. Figured as **Alaria unicornis**: W. H. Hudleston, Mon. Pal. Soc., 1888, pl. v., f. 1, p. 119.
Inferior Oolite. [8081] Nailsworth.

Scalaria pygmæa, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5366] Leckhampton.

Spinigera didactyla, Hudleston, *var.*
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. iii., f. 6*d*. p. 106.
Inferior Oolite. [8101] Bradford Abbas?

Spinigera recurva, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. iii., f. 5*f*, p. 105.
Inferior Oolite. [8100] Bridport.

Straparollus "tuberculosus-dexter," Hudleston.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xxvi., f. 1, p. 317.
Inferior Oolite. [8036] Dundry

Trochotoma calix (Phillips).
J. Lycett, "Cotteswold Hills" 1857, pl. iii., f. 6, p. 166.
Inferior Oolite. [8028] Cotteswold Hills.

Trochotoma carinata, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78; Figured "Cotteswold Hills" 1857, pl. iv., f. 5, p. 167.
Inferior Oolite. [8027] Rodborough.

Trochotoma depressiuscula, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [8114] Rodborough.

Trochus alternans, Lycett. T
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [5354] Leckhampton.

Trochus bi-cingendus, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416; Proc. Cotteswold Nat., vol. i., 1853, p. 77. Figured as **Trochus? bicingendus**: W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xxxi., f. 15, p. 389.
Inferior Oolite. [8041] Nailsworth.

Trochus cingillato-serratus, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [5357] Leckhampton.

Trochus pileus, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [5358] Leckhampton.

Turbo cheltensis, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416; Proc. Cotteswold Nat., vol. i., 1853, p. 77.
Inferior Oolite. [5353] Leckhampton.

Turbo elaboratus, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, pl. xi., f. 1, p. 416; Proc. Cotteswold Nat., vol. i., 1853, pl. ii., f. 1, p. 77. Refigured as **Purpurina sp. [P. aperta]**: W. H. Hudleston, Mon. Pal. Soc., 1888, pl. i., f. 4 *a*, *b*, p. 87.
Inferior Oolite. [8097] Nailsworth.

Turbo Etheridgii, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. vi., f. 3, p. 125. Refigured as **Cirrus Etheridgii**: W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xxiv., f. 15, p. 306.
Inferior Oolite (Gryphite-grit) [8026] Rodborough Hill.

Turbo oppelensis, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. iii., f. 8, p. 127. Refigured as **Hamusina oppelensis**: W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xxiv., f. 14, p. 305.
Inferior Oolite. [8050] Nailsworth.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

AND

MUSEUM OF PRACTICAL GEOLOGY

FOR

1903.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY.

AND

MUSEUM

FOR 1903.

INTRODUCTION.

By J. J. H. TEALL, M.A., D.Sc., F.R.S., Director.

The field-work for the year 1903 followed on the lines of the work of the previous year. In England, progress has been made with the re-survey of Cornwall, South Wales, and the counties of Derby and Nottingham; in Scotland, with the original survey of the Highlands and Western Isles, and also with the revision of the Coal-Fields; in Ireland, the area around Cork has been surveyed for drift. An account of the work done will be found in the following pages, arranged under the several districts, so that it will be unnecessary to do more, in this Introduction, than to call attention to a few of the more salient features.

Economics.

In a general review of the work of the year it is fitting that special reference should be made to that portion of it which bears directly on the economic problems of the present day; but it should not be forgotten that the object of the Survey is to ascertain the geological structure of all parts of the country, and that the present value of the work must, therefore, vary according to the nature of the district in which it is carried on. All maps on which the distribution of the rock-formations is accurately represented must be of value, but those of districts in which beds of coal, oil-shale, or metalliferous lodes occur, are of special importance at the present time. Much of the work of the past year has been carried on in such districts. In South Wales, the mapping of the main coal-field is now on the point of completion, and that of the Pembroke coal-field has commenced. The extreme west end of the main coal-field has been less thoroughly exploited than the other parts, and many problems of great economic importance connected with its structure, the correlation of the seams, the limits of the anthracite region, and the extension of the Coal measures under the sea, await solution. The whole region which has been under examination during the

conomics. past year, and which extends beyond the boundary of the coal-field, is traversed by great disturbances. The one furthest south runs east and west, and appears to belong to the pre-Triassic system which determines the structure of Gower. The others range about west-south-west, and connect themselves with the system of which Cribarth and the Vale of Neath furnish notable examples. They succeed each other at more or less regular intervals, but with a tendency to increase in frequency and intensity towards the north-west. As they run in the direction of the strike, and have the effect of cutting out, or, at times, of repeating the outcrops, much of the district is not suited for giving a comprehensive view of the sequence or yielding measurements of thickness.

In the Midland District progress has been made with the survey of the southern part of the Derbyshire and Nottinghamshire coal-field, a large part of which is concealed beneath Permian and Triassic rocks. In the course of the year it has been ascertained that certain disturbances in the overlying rocks correspond with faults in the Coal-measures below, thus bearing out the view expressed in the Introduction to the Summary for 1902, that a detailed survey of the Permian and Trias will probably throw important light on the structure of the concealed coal-field, notwithstanding the fact that this structure has, in the main, been determined by earth-movements of pre-Permian age.

In Scotland the revision of the Carboniferous areas in East Lothian, Midlothian, and West Lothian has been continued with the result that some modifications of the lines, as laid down by the earlier survey will have to be made, especially on the south-west margin of the Midlothian coal-field in the neighbourhood of Penicuik. The oil-shale fields have received special attention.

In Cornwall the work of recording the positions of the more important lodes on the six-inch maps is approaching completion, and much information as to the nature of the lodes, their relation to the granite, and the distribution of ore-bodies, has been collected. Some of the results that have been obtained are briefly summarized in the following pages.

An interesting discovery of tin in Scotland may be referred to in this connexion, although it is impossible at present to say whether this discovery is likely to prove of economic importance. Unlike the tin in Cornwall, it occurs in association with magnetite and forms part of a rock essentially composed of magnetite and cassiterite. Several specimens have been examined, and it has been found that the cassiterite is distributed in a sporadic manner, varying from nil to 17 per cent. No minerals containing boron or fluorine, such as occur so abundantly in association with tin in Cornwall and elsewhere, have as yet been found either in the magnetite-cassiterite rock or in the rocks with which it is associated. The facts as known suggest many interesting speculations which may, however, be appropriately withheld until the district has been re-visited, and all available information has been obtained. There is no reason at present to believe that the magnetite-cassiterite rock occurs in any large masses.

Highland Metamorpl Rocks.

Considerable tracts composed of metamorphic rocks have been surveyed in the West Highland and North Highland Districts, but with one or two exceptions no new petrological types have been met with. The oldest group of rocks, if we except the small areas somewhat doubtfully referred to the Lewisian gneiss, are of sedimentary origin, though possibly not all belonging to the same formation. In the area, to the north of the Caledonian canal in which work has been carried on during 1903, these sediments are principally represented by two types which shade into each other, but which are as a rule fairly distinct; the one may be described as the quartzose or quartzo-felspathic type representing arenaceous or psammitic sediments, and the other as the micaceous type representing muddy, argillaceous or pelitic sediments. Both types are now in the crystalline condition, and distinct traces of original clastic structure are only seen in the coarser varieties of the arenaceous type. This sedimentary series has been greatly disturbed and invaded by plutonic igneous rocks of granitic character. The earlier intrusions have been more or less folded and foliated with the sediments, but the later intrusions are usually massive, and give no indication of having been seriously affected by earth-movements subsequent to consolidation.

In the Summary of Progress for 1902 evidence was brought forward to show that in central Ross-shire important movements resulting in the formation of crystalline schists of both igneous and sedimentary origin, had taken place subsequent to the intrusion of granitic rocks and the consequent metamorphism of the surrounding sediments. The determination of the relation in point of age between the folding of the sediments and the intrusion of the plutonic masses is of considerable theoretical interest, but not unattended with difficulty. In regions such as the Southern Uplands, the Lake District, and Cornwall, the intrusions took place after the movements which produced the folding, and cleavage of the surrounding sediments had practically ceased; but in the Highlands this is certainly not the case as regards the *earlier*, though it is approximately true as regards the *later* intrusions. It is quite possible, however, that considerable folding of the sediments had been produced before any intrusion took place, and that the movements were prolonged during and subsequent to intrusion, consolidation and contact-metamorphism. In the following pages the effects of these subsequent movements in modifying the structure and composition, not only of the igneous rocks but also of the contact-metamorphosed sediments, is strongly emphasized. Two new petrological types have been met with during the year: the one is an ægirine-riebeckite gneiss, and the other is the magnetite-cassiterite rock, to which reference has already been made.

In the districts to the south of the Caledonian Canal, in which work has been carried on, less highly metamorphosed rocks similar to those belonging to the Perthshire series have been met with.

Torridonian, Ordovician, Old Red Sandstone and Devonian rocks have been surveyed during the year, but no facts of general importance have been brought to light.

arboni-rous ocks.

The Carboniferous formation naturally receives a considerable amount of attention in the following pages, but the facts recorded are principally of local importance. One point of general interest may, however, be especially noted.

As is well known, the vertical distribution of both plants and fishes points to a two-fold division of the Carboniferous rocks, but the precise nature and position of the boundary line or zone in any given area is more or less uncertain. The common three-fold division into Carboniferous Limestone, Millstone-grit and Coal-measures has no palæontological basis and the distinctive lithological characters connoted by these terms are not persistent, so that the boundary lines as drawn on the maps are often arbitrary and the terms misleading. This being the case, advantage has been taken of the revision of the Midlothian Coal-field to collect carefully both plants and fishes from all possible horizons in the so-called Millstone-grit or Roslin Sandstone series, with the result that the palæontological boundary line has been fixed in this area with a very great degree of accuracy. It occurs about one-third of the way up in the Roslin Sandstone series. In carrying out this investigation the Geological Survey has had the invaluable assistance of Mr. Kidston and Dr. Traquair. The fossils collected were sent to these gentlemen, who reported upon them independently. It is not a little remarkable that such a striking change in the flora and fish-fauna should occur in a sedimentary series in which there is no indication of an unconformability or of any marked change in lithological characters.

It is not proposed to make any change in the method of representing the geological structure of the district in consequence of this work. The Roslin Sandstone series will be indicated upon the map as before, on account of its distinctive lithological features, but the approximate position of the line or zone separating the Lower from the Upper Carboniferous rocks will also be shown.

'ermian and 'rias.

Rocks belonging to the Permian and Trias have been surveyed on the margin of the exposed part of the Derbyshire and Nottinghamshire coal-field. The results confirm the work of previous observers, as to the marked unconformability at the base of the Permian, and the intimate relation between the Permian and Bunter. The boundary lines between the Permian and Bunter, and between the various subdivisions of the latter, are often more or less arbitrary, and it is, therefore, not surprising to find that the new lines do not in all cases agree with those laid down in the earlier maps.

'ertiary.

Some interesting particulars with reference to Tertiary igneous rocks will be found in that portion of the Summary which deals with the district of the Small Isles. Additional evidence of the formation of banded gneisses of Tertiary age has been found. Thus Mr. Harker states "that a large amount of eucrite has

become enveloped and partially incorporated in a granitic magma, the whole being then drawn out into bands while still effectively fluid."

Much information as to the drift deposits of the several districts will be found in the following pages. Perhaps the most interesting result of the work of the year, so far as the Pleistocene period is concerned, is the recognition in the Cork area of a pre-glacial beach slightly elevated above the present level of the sea, and agreeing in position with the raised beaches of the same age in Gower and Bridlington. Evidence is, therefore, accumulating that, in spite of changes during and subsequent to the glacial period, the level of the sea immediately before that period was approximately the same as it is at present. Pleistocene and Recen

In the course of the year much work has been done for the Royal Commission on Coal Supplies, especially by Mr. Strahan, who is now a member of the Commission. The six-inch maps of the South Wales coal-field have been frequently consulted by the engineers and others who are engaged in making the estimate of available coal in that district, and have proved of great value for the purpose. Miscellaneo

During the year the Memoir on the Cheadle Coal-field, by Mr. George Barrow, was published, and it was there confidently asserted that the valuable Dilhorne seam existed in a region in which it was supposed to be absent. This prediction has since been verified.*

The bearing of the work of the Geological Survey on Agriculture is the subject of a paper by Mr. H. B. Woodward, who contributes a report on the soils and subsoils of the Rothamsted estate.

Brief notes on other matters of economic importance, will be found in the portions dealing with the several districts.

I.—ENGLAND AND WALES.

I.—FIELD-WORK.

The ground to be surveyed was arranged in three areas under the District Geologists, as follows :— Mr. Woodward.

1. Midland district under Mr. C. Fox-Strangways.
2. Southern district under Mr. Clement Reid, F.R.S.
3. South Wales district under Mr. A. Strahan, M.A., F.R.S.

In the *Midland district* the work was carried on mainly in sheet 125 (Derby, etc.), the area of which was completely surveyed. This includes the southern portion of the Derbyshire and Nottinghamshire coal-field with bordering Lower Carboniferous, Permian,

* See *Colliery Guardian* for May 27, 1904; and *Geol. Mag.* for 1904, p. 323.

and Triassic rocks. Field-work was also carried eastwards near Southwell in Sheet 126 (Nottingham), on the Triassic strata and drifts. The district memoir on the North Staffordshire coal-fields, that on sheet 141 (the country between Derby and Loughborough), and a second edition of that on sheets 54 and 55 (the Oolitic and Cretaceous rocks south of Scarborough) are in type. The memoir on sheet 110 (the country around Congleton, Macclesfield, etc.) has been completed, but that on the Leicestershire coal-field is still in hand.

In the *Southern district* the survey of sheets 346 (Newquay) and 352 (Falmouth and Truro) has been completed, and that of sheet 357 and 360 (Scilly Islands) has been commenced.

The mining information relating to the Land's End district, and much of that in the Camborne district, has been obtained from various mine-plans, supplemented in some cases by underground inspection. The memoir on sheets 355 and 356 (the country around Kingsbridge and Salcombe) is in type, and that on sheet 349 (the country east of Plymouth), and others are in hand.

In the *South Wales district* considerable progress has been made in the survey of sheet 229 (Carmarthen and Kidwelly), so that the mapping of the main coal-field of South Wales is almost completed. Further mining information has been collected in the area of sheets 230 (Ammanford or Cross Inn) and 246 (Worms Head); but in an imperfectly proved district near Kidwelly, there has still to be gathered some information, which will have a bearing on the extent of the Coal-measures under Carmarthen Bay. The field-work has been carried westwards into Pembrokeshire in sheet 228 (Haverfordwest). Several colour-printed maps of the South Wales coal-field have been prepared to replace the hand-coloured sheets. The memoirs on sheet 231 (the country around Merthyr Tydvil), and on sheets 261 and 262 (the country around Bridgend) are in type.

Examinations have been made of the following new railway cuttings: (1) New Cross; (2) between Uxbridge and Loudwater; (3) near Chipping Sodbury in Gloucestershire; and (4) on the Leek and Cauldron Light Railway in Staffordshire.

Notice was sent to the Geological Survey Office of a reported occurrence of fuller's earth at Hazelbourne, north-east of Dorking station (L. B. & S. C. R.). A shaft had been sunk into the lowest portion of the Chalk, and the grey marl of that formation had been taken for fuller's earth. In aspect and texture the material indeed much resembled some varieties of economic fuller's earth, but all of it was more or less plastic and highly calcareous. The following fossils obtained from this Chalk marl were named by Mr. E. T. Newton:—

Ammonites [Schloenbachia] varians, *Sow.*
——— [Acanthoceras] navicularis, *Mant.*
Plicatula inflata, *Sow.*
Inoceramus latus ? *d'Orb.*
Ostrea vesicularis ? *Lam. non Mant.*

1. Midland District—Derbyshire and Nottinghamshire.

Mr. C. Fox-Strangways, District Geologist.
Mr. B. S. N. Wilkinson
Mr. W. Gibson, B.Sc.
Mr. T. I. Pocock, M.A. } Geologists.
Mr. C. B. Wedd, B.A.
Mr. R. L. Sherlock, B.Sc.

Mr. Fox-Strangway

The area that was completed during the year comprises the southern part of the Derbyshire and Nottinghamshire coal-field, and is in reality a prolongation of the great coal-field of Yorkshire. The coal-field occupies a basin whose southern limits between Derby and Nottingham are to some extent concealed beneath Triassic marls and sandstones, while the eastern portion is more largely concealed by the Magnesian Limestone and overlying Triassic deposits. The Coal-measures are exposed over a broad tract drained by the Erewash, and they extend westwards to near the Derwent Valley at Belper. Here we reach the margin of the basin formed by the Millstone Grit Series, which from near Duffield northwards to near Wirksworth extends in bold and rounded hills, for the most part under cultivation, but with occasional rocky scarps. Still further west the Pendleside Series and the Carboniferous Limestone rise on the borders of the great anticline of the Derbyshire Dale district.

CARBONIFEROUS.

Carboniferous Limestone.

Mr. Pocock

Only an area of between two and three miles of Carboniferous Limestone has yet been mapped around Wirksworth. It has an irregular boundary, which is in nearly every case a line of fault. The thin-bedded cherty limestones at the top have been separated out from the more massive beds below; and the result tends to show that the thickness has been exaggerated. The cherty beds do not appear to be more than from 40 to 50 feet thick, and 130 feet more would probably include all the beds down to the Toadstone of Middleton. This agrees more closely with the estimate of thickness at Matlock than with that given for Wirksworth.* Much of the limestone is dolomitic. The Toadstone of Hopton, marked on the old map as Greenstone, is a coarse brecciated ash.

Pendleside Series ("*Yoredale Rocks*").

Mr. Wedd

This series from the base of the Kinder Scout Grit consists of the following sub-divisions:—

3. Shales with two thick beds of fine-grained grit, the higher one being sometimes upwards of 30 feet in thickness; and a large number of thin flaggy beds of similar grit. A few traces of plants have been found but no other fossils.

* See Hor. Sect. of the Geological Survey, Sheet 60; and Memoir on North Derbyshire, pp. 22–24.

. Wedd.

2. Shales with occasional bands of hard, fine-grained siliceous grit only a few inches in thickness, and having much the aspect of the thicker crowstones of North Staffordshire. *Goniatites, Posidoniella, Posidonomya ? Aviculopecten,* and plants occur at several horizons.

1. Shales, often black, with thin beds of hard dark or light grey earthy limestone. These limestones are seldom more than about a foot in thickness; but near the base thicker beds come in, which more closely approximate to the type of the Main Limestone. The same genera as those above occur at several horizons, but the general fauna of the Main Limestone seems not to extend above the thicker beds of limestone near the base of this series.

1. The lower beds are exposed in a stream at the east end of the Crich inlier, where beds of limestone are seen three or more feet in thickness, similar in character to the Main Limestone, and probably only separated from it by a few feet of shales. One of these beds, 2 feet thick, was silicified. Somewhat higher beds composed of dark, calcareous and pyritous shales containing *Glyphioceras falcatum*, and one or two other forms of *Goniatites* appear in the stream south of Wate Bridge. At Windley and Kedleston shales with thin limestones, doubtless somewhat higher, occur. At Windley these contain *Goniatites* and plants in the same bed of fissile limestone.

2. The middle portion of the series occupies a broad tract of country ranging by Breadsall, Allestree, Windley and Shottle to Wirksworth. The thin crowstones, economically of no value, are seldom exposed in artificial sections, but they make a marked effect on the landscape, and often produce features of considerable size by protecting the underlying shales.

3. A strong grit of this group is seen in the west bank of the Derwent at Burley Hill, opposite to Little Eaton, and is probably the grit seen in the railway cutting (Wirksworth branch) near Duffield Station. Above this bed at Duffield numerous small grit beds crop out. Still higher beds crop out north-west of Duffield; where a grit, upwards of 30 feet thick, forms the brow along which the Hazlewood road runs. Several grits of like nature, one or two of them 20 feet or more in thickness, are seen west of Handley Wood, south-west of Ashleyhay, and near Gibbet Wood.

The Goniatites are badly preserved and have not yet been completely determined. *Glyphioceras falcatum* and *Glyphioceras bilingue* appear to range throughout the fossiliferous part of the Pendleside Series, and *Glyphioceras spirale* was noticed near the top of it. *Gastrioceras carbonarium* and *Gastrioceras Listeri*, which form nearly the whole of the Goniatite fauna in the roof of one of the lower coals at Ambergate Brickworks, have not been seen in the Pendleside Series.

r. Pocock.

East of Wirksworth the "shales with thin limestones" above the Carboniferous Limestone as far as the first sandstone bed are about 250 feet thick.

The sandstones with shale beds, which were grouped together by Professor Green under the name "Shale Grit," have been separated into three or four beds. At Kirk Ireton, where they are well developed, their united thickness is about 150 feet. These sandstones seem to die out further south; but at Kirk Langley some intensely hard sandstones are seen in the Carboniferous inlier, which were compared by Professor Green to the crowstones of Staffordshire and Cheshire. Owing to the covering of Trias here their relation to the softer sandstones further north is not clearly seen. Mr. Pocock.

The staining of these beds by the overlying Bunter is interesting. The section in Croft Wood near Breadsall Station was noticed last year.* Since then it has been observed that very frequently around outcrops of Bunter a bright red clay soil is found, containing usually abundance of Bunter pebbles. At first sight it suggested Drift, but its colour is brighter than that of the usual red Boulder-clay, and its position implies staining of the Carboniferous shales. In Breward's Carr, near Windley, good sections clearly show this staining of the Carboniferous rocks. Here soft shales, weathered, but still retaining their bedding and dip, become bright red and pure white, the red being more vivid as it approaches the Bunter. Thin bands of grit and limestone are stained in a similar way, while the soil of the neighbouring fields shows the same colour. Mr. Wedd.

Millstone Grit.

A general description and classification of the Millstone Grit of the district was given in last year's Summary of Progress.

The Kinder Scout Grit.—The massive grit, generally coarse-grained and more or less pebbly, which is believed to be a continuation of the Kinder Scout Grit, presents some difficulty in mapping owing to the variability and uncertainty of its base. The great mass of grit, which forms the high ground of Breadsall Moor, appears to diminish northwards by the separation of its lower part from the main mass; this becomes thinner at first, and possibly dies out, but eventually recovers itself northwestward, and becomes a massive grit perhaps equal in thickness to the upper part, but separated from it by a considerable thickness of shale. At the same time the upper grit diminishes northwards.

The grit of Breadsall Moor, of great but unknown thickness, seems to be composed of lenticles which separate out by denudation, as the grit approaches the valley of Bottle Brook. The base of the mass crops out in Camp Wood. On the north-west side of Bottle Brook a steep escarpment of grit surmounts a gentle slope in Duffield Bank, and can be followed to Jack o' Darley's Bridge at Little

* Summary of Progress for 1902, pp. 17, 18.

Mr. Wedd. Eaton; it can be recognised on the east side of Bottle Brook, and is clearly much higher than the grit of Camp Wood. At Outwoods, on the top of the escarpment, a boring lately sunk proved grit to a depth of 320 feet, the uppermost 17 feet being Drift. The bottom of the rock was not reached.

Beds between the Kinder Scout Grit and the Third Grit.—Throughout the northern half of the district a coal lies immediately above the Kinder Scout Grit, and was formerly worked in several places. It was recently exposed at the east end of Belper Lane, where it was seen to be more than 2 feet thick. At the Alderwasley Pipe Works, near Whatstandwell, a coal about 2 feet thick is now worked, 60 feet below the Third Grit; while the underlying fireclay is used for drainpipes. It is not unlikely that this coal, which was formerly worked beneath several of the outliers of Third Grit, is a higher seam. A fine-grained grit occurs in these measures,* which at Milford is separated into two distinct beds. These cannot be traced north of Belper, though here and there thin beds of grit appear between the Kinder Scout and Third Grit. The argillaceous beds between the two grits consist chiefly of blue shales, which are extensively used for brick-making at Milford. The series may be upwards of 200 feet thick north of Belper, but between Whatstandwell and Crich it is probably not more than 100 feet.

At Whatstandwell a bed with *Lingula mytiloides* was found in shales about 30 feet below the Third Grit.

The Third Grit.—In the neighbourhood of Whatstandwell and Coddington this grit makes a series of outliers within the shallow basin of the Kinder Scout Grit. It is generally a fine-grained, white, purple or red grit, free from pebbles; but north of Ambergate it begins to become somewhat coarser, and contains occasional small pebbles.

It was stated in the Summary for last year that the anticlinal uplift shown by the inlier of Carboniferous Limestone at Crich might be regarded as the key to the structure of the neighbourhood; and that north of Ambergate the eastern limb has a steep easterly dip from Bullbridge to east of Crich; while the Kinder Scout Grit of the western limb has a gentler westerly dip. Two distinct anticlinal domes are seen in the Crich limestone, both trending north-west, and repeated by a fault. The eastern dome is not seen elsewhere, but its axis can be traced from Hilts Quarry to the quarry below Crich Stand, and seems to cause the curving outcrop of the strata recognisable as far as Pentrich; while the influence of the western anticline is seen by the sharp fold which it makes as far south as Ambergate, only dying out completely some distance farther south. Between Crich and Wirksworth the strata lie in a shallow syncline, which can be recognised as far south as Milford. In the neighbourhood of Hazlewood and Shottle the shales below the Millstone Grit

* Summary of Progress for 1902, p. 11.

lose their regular easterly dip, and are irregularly folded; but this does not perceptibly affect the general lines of outcrop, for no large folds are seen, and it is probable that the beds are merely puckered into small wrinkles. Mr. Wedd.

Coal Measures.

In the Erewash Valley the measures cropping out include the strata and accompanying coal seams from the Kilburn Coal on the south and south-west to about 500 feet above the Top Hard Coal on the east, the higher beds being then concealed under newer deposits. The total average thickness of exposed Coal-measures amounts to nearly 2,000 feet. This great thickness is made up chiefly of shales and clays, sandstones being quite subordinate except near the base. The soft nature of the material is reflected in the scenery, which is gently undulating and void of bold features. There is an absence too of stone buildings and stone walls, so characteristic of the Yorkshire coalfield, where the sandstones have increased in thickness, and supply abundant building-material. Mr. Gibson

In the Erewash Valley the strata are thrown into gentle folds. An anticline, of which the western limb is the more highly inclined, coincides with the alluvium of the valley from near Trowell on the south to a little north of Langley Mills. At this point it leaves the alluvial flat, and the axis coincides with the ridge of Codnor Park and Rhyddings. Two shallow synclines, on which the towns of Heanor and Ripley are situated, succeed to the west.

On the east side of the valley the strata dip uniformly eastward. The faults of the area belong to two directions. The best defined have a N.N.W. and S.S.E. trend, and occur in groups. Thus a group of faults having this direction intersects the syncline at Ripley, their throws reaching a maximum towards the centre of the basin. Similarly the Heanor and Shipley syncline is bounded by two faults, decreasing in throw northward. It would therefore appear that an area of little or no faulting separates the Ripley and Heanor synclines.

The anticline of the Erewash Valley is intersected by faults, but again an area of little faulting occurs north of Langley Mills, on a line with that dividing the faulted belts of Heanor and Ripley. A third group of faults breaks the measures between Eastwood and Kimberley.

Faults with an east and west direction are rare. The best defined is the one extending from Cinderhill to Kimberley, north of which it would appear to bend northwards and so merge into the northerly system of faulting. It would also appear that the east and west faults traversing the Triassic rocks of Lenton and Bramcote Hills bend northwards near Trowell, and join the Erewash Valley anticlinal faults. An east and west fault crosses the Erewash Valley

Mr. Gibson. at Codnor Park Station; this is continued eastwards up the Bagthorpe Valley, and probably joins the east and west fault of Annesley Park.

PERMIAN.

Mr. Sherlock. In the country to the north there are two beds of Magnesian Limestone separated by an intervening series of marls and sandstones; but in this district this is not the case, and the following may be taken as the Permian sequence :—

Red marl and sandstones.
Magnesian Limestone.
Breccia.

Mr. Gibson. The Magnesian Limestone rests unconformably on the Coal-measures, and occasionally a basal breccia is seen which contains fragments of Carboniferous Limestone, and many other kinds of rock.

The well-defined escarpment from Strelley northwards bounds the exposed part of the Coal-field on the east; and it may be observed that a little south of Strelley the basal beds rest on measures associated with the Waterloo Coal, a seam twenty yards below the Top Hard Coal, and near Kirby Woodhouse on beds about 500 feet above this coal.

In the neighbourhood of Kimberley we have no important additions or alterations to make to the admirable account of the Permian rocks by E. Wilson.*

Mr. Sherlock. In Grives Wood near Kirkby in Ashfield some shale occurs between the limestone and the breccia, which is not found further south. *Schizodus* and Foraminifera occur in bands of limestone in the shales.

The Magnesian Limestone is throughout the district a granular brown, flaggy rock, closely resembling a sandstone in appearance. A lens, however, shows that the grains are rhombohedra of dolomite. The outcrop produces a remarkably flat surface, but broken at times by low mounds, 20 to 30 feet high, usually arranged in lines, which are formed by anticlines in the limestone, where the normal dip of 1° to 2° passes quite suddenly into one of 20° to 30° or more. These mounds have been found to exactly coincide with faults in the Coal-measures below; and it may eventually be found possible to foretell the position of some of the faults in unworked areas by means of these ridges. The main anticlinal axis runs from Aldercar Wood through Linbyhill Farm, and thence follows the Great Central Railway to Hucknall and Farley's Lane, finally dying out in Bulwell. There is another much shorter ridge behind the rectory at Linby.

* *Quart. Journ. Geol. Soc.*, vol. xxxii., pp. 533–537 (1876).

The same phenomenon has been observed near Southwell. In the stream known as Westhorpe Dumble, immediately east of the bridge between Holme Lane and Candy Hill, the beds are seen to be suddenly tilted up, forming a sharp anticlinal fold, the axis of which seems to run in a direction N. 10° W. and S. 10° E. The second instance is in the stream which traverses the vale between Challard's Farm and Holbeck Farm and runs down to the village of Hallam. The beds of sandstone are here tilted up to as high an angle as 40°. Although no actual fracture of the strata can be seen, there seems to be a line of disturbance running in a N.E. and S.W. direction. In both these instances it is possible that they may be owing to a fault occurring in the underlying strata. Mr. Wilkinson.

The Permian red marl rests conformably on the Magnesian Limestone, and in its upper part passes, by the intercalation of fine grained sandstone, into typical Bunter. A good section of this is seen in the cutting of the Great Central and Great Northern Railways north of Annesley tunnel. The sketch (Fig. 1, p. 14) shows the relation of the beds at this place. Mr. Sherlock

Much of the section is overgrown, but measurements have been made at the four places indicated by vertical lines. The bed marked (*i*) is apparently the representative of beds (*b*, *c*, *d*, and *e*). The unshaded portions consist of sandstone and marl, but these, in the absence of direct measurements, have not been indicated. At the other end of the tunnel, 980 yards to the east, the dip of the strata brings normal Bunter sandstone into the cutting, and it is seen to pass down into the alternations of marl and sandstone exposed in the section figured.

At Papplewich the outcrop of the marls and of the Lower Red Sandstone of the Bunter is particularly narrow, the latter diminishing from about 100 feet at Annesley tunnel to about 20 feet at Papplewich. This may be due to the overlap of the Bunter Pebble Beds; but it seems more probable that the red marl is to some extent replaced by sandstone, and the Lower Red Sandstone by Pebble Beds.

TRIAS.

Bunter.

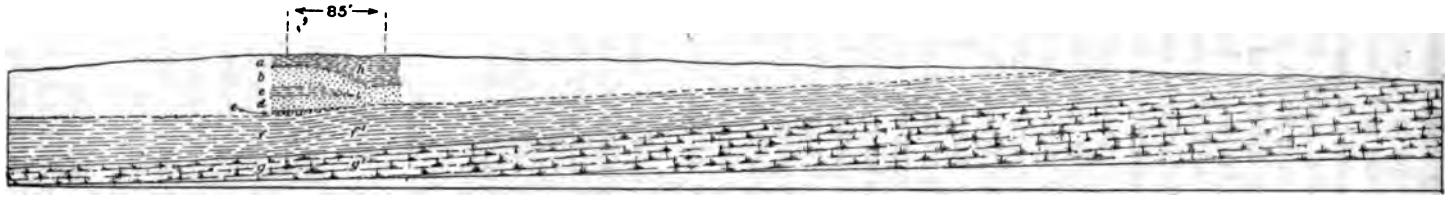
In the country north of Derby the Bunter consists entirely of soft, buff, coarse sandstone, or loose sand with scattered pebbles, and beds of shingle. It here contains no red sandstone, and is very variable in thickness, having a tendency to die out towards the north-west. Its variability of thickness is probably owing to the uneven surface of the Carboniferous rocks upon which it lies. The Pebble Beds occupy a rather larger area than was shown on the old map. Mr. Wedd.

In the district north of Nottingham a Lower Red Sandstone has been separated out from the Pebble Beds, which, as we have stated, passes down into the underlying marls. Thin bands of red marl Mr. Sherlock

Fig. 1. *Section along the Great Central Railway, N.W. of Annesley Tunnel.*

Length of the section = 1250 ft.

Horizontal scale 1 in. = 200 ft. Vertical scale three times the horizontal.



(*a*) Red Marl, 2 ft. 9 in. - - - . (*h*) Red Marl, 8 ft.
(*b*) Sandstone, 6 ft. 6 in.
(*c*) Red Marl, 1 ft. 9 in.
(*d*) Sandstone, 5 ft. 6 in. - - (*i*) Sandstone, 6 ft. 2 in.
(*e*) Greenish Sandstone, 1 ft.
(*f*) Red Marl. - - - - - - (*f'*) Red Marl, 13 ft.
(*g*) Magnesian Limestone. - - - - (*g'*) Magnesian Limestone, 7 ft.

may also be seen in this sandstone in many places, being most pronounced in the lower beds, but lenticles also occur even in the Pebble Beds as at Bestwood Warren. Similarly lenticular beds of pebbles, usually very small, occur in the Lower Red Sandstone, and merely become more numerous and larger in the Pebble Beds. In a sand pit north of Hucknall Colliery Railway a bed of red marl is seen passing laterally into sandstone. The fact is the sub-divisions of the Bunter in this area are merely conventional, and have very indefinite boundaries. Mr. Sherlock

The Lower Bunter, which as we have said is best seen in the cutting west of Annesley tunnel, resembles Keuper rather than Bunter, but the typical Bunter aspect comes in with the higher beds.

Throughout this area the Bunter is very soft, and even the Pebble Beds are so incoherent that at Bestwood they are used for moulding sand.

Keuper Sandstone.

These beds are thin sandstones much mixed with red marls. Where it has been possible to separate them from the main mass of red marl above it has been found convenient to take the boundary at a slightly higher horizon than was done on the old map, consequently a considerably larger area has been shown as Keuper Sandstone. Mr. Pocock.

At Allestree a small thickness of fine-grained soft brown sandstone occurs at the base of the marls, and a little higher there are several thin beds of harder buff sandstone, often honey-combed on the weathered surface. Both these sandstones contain small white quartz pebbles. Mr. Wedd.

Some part of the ground represented on the old map as Bunter at Weston Underwood and Kedleston is now found to be Keuper Marl.

At Southwell the Keuper Sandstone consists of beds of soft, flaggy, red sandstone usually about 1 foot to 1 foot 6 inches in thickness, but the more massive beds are the exception. On the surface of the flaggy beds ripple marks are of very common occurrence. Some of the beds are greenish, but seem to pass rapidly into the red portions. Rather shaly beds occur at intervals, and being somewhat impervious, the water flows along them and forms in one or two instances rather copious springs. Mr. Wilkinson.

Keuper Marl.

The upper division of the Keuper consists of stiff red marls, occasionally variegated with streaks of green marl. In these marls very thin beds of white or greenish white sandstone occur, which are of no economic use. These beds lie nearly horizontal so that the beds of sandstone crop out here and there along the slopes of the hills; in many instances they can only be followed by the greenish colour of the soil in ploughed fields.

PLEISTOCENE.

Glacial.

The central portion of this district is clear of glacial deposits, but they come on again on either side of the Erewash Valley.

Mr. Pocock. To the north of Derby the Drift runs up to a height of over 1,000 feet, the highest altitude in the district, and is mainly Boulder-clay composed largely of Bunter pebbles in a red clay matrix; which, in the absence of sections, is difficult to distinguish from a Bunter soil. New sections have proved that some of what was shown on the old map as Bunter is in reality Drift.

There are very few fluvio-glacial deposits compared with other districts, but fine examples have been mapped on the heights between Kirk Ireton and Ireton Wood. They occur to some extent also in the Wirksworth Valley, a small area of them having been mapped at Idridgehay.

Mr. Wedd. East of this the Drift is found chiefly upon the higher tracts of the Carboniferous shale below the outcrop of the Millstone Grit, but the thickest deposit fills a valley between the two anticlinal ridges of limestone at Crich. This valley, which has a north-westerly trend, was completely filled with Boulder-clay having a thickness of 50 feet and possibly much more. The limestone on both sides bears striæ running S.S.E. The lower part of the Boulder-clay on the west side of the valley is seen at Hilts Quarry to contain thin beds of clean sand and gravel.

The most extensive tract of Boulder-clay is at Shottle, where besides capping the higher ground it fills the valley of Franker Brook, which is thus seen to be pre-glacial, as are also some of the other minor valleys of the district. A well-defined patch of Boulder-clay caps the high ground at Hazlewood, and there is also an elevated plateau at Ashleyhay.

At Windley and farther south a peculiar type of Drift gravel occurs. It usually lies upon or in the neighbourhood of Bunter Sandstone, and consists wholly, or almost wholly, of re-arranged Bunter material, which is sometimes difficult to distinguish from Bunter. In clear sections the pebbles are, however, seen to lie more irregularly than in the Bunter, while pitted pebbles are less frequent and distinct. Almost the whole of the boulders and stones in the Drift are of local origin, but a few north-country rock fragments also occur. A rounded boulder of Buttermere granophyre, about 1 foot in diameter, was found at Shottle; a large boulder of a dark andesitic rock, similar to a common type in the Lake District, at Moorwood Moor; an andesite with garnets at Hazlewood; and several small foreign erratics at Crich, including two or three coarse-grained white granites. Certain pebbles of igneous rock found at the surface are, however, derived from the Bunter.

[illegible]son. On the eastern side of the Erewash valley a considerable quantity of Drift has been met with. This consists largely of sand and gravel, patches being certainly met with as far south as Hollybush Farm

near Watnall; while the gravelly deposits near Nuthall Temple and Strelley Hall are also probably of glacial origin. It is, however, near the head of the valley, south of the Portland Collieries, that the thickest and most extensive masses are met with. In a large quarry south of No. 4 shaft, about 6 feet of chocolate-coloured clay overlies some 70 feet of loose sand, containing thin layers of leafy clay. The same kind of material can be traced at intervals to Underwood, near which place and at Friezeland it has been opened in sand pits. That this Drift is the product of the western ice-sheet is shown by the boulders of Lake District rocks met with around Friezeland; and that it was laid down near the margin of the eastern ice-sheet becomes apparent from the occurrence of thin Drift containing flints on the eastern borders at Friezeland. From the occurrence also of gravelly and clayey deposits with boulders of Lake District rocks on or around the Long Hills, it becomes evident that the western ice-sheet surmounted the low scarp of the Magnesian Limestone, though no striæ have been met with on this comparatively hard rock. Mr. Gibson.

In Annesley Park there is a prominent ridge of Drift running from Diadem Hill to Patrick Plantation; here there is a section which shows a mass of pebbles of great variety sometimes cemented into a conglomerate, and in one case forming an enormous block many feet in length. Some of the pebbles are most probably of Jurassic age. The prominent knoll of Bunter near Newstead Station, called Hazleford Cliff, has some curious striæ pointing in a N.W. and S.E. direction, which may be of glacial origin. There is a considerable amount of Drift in this area, but, as a rule, it is very thin. It would be difficult to find a single field which is not sprinkled with Drift pebbles, but usually there is not enough to map. The sand and gravel present exceptional difficulties from the fact that they lie on or very close to the Bunter from which they have been formed, so that the Drift and the incoherent Bunter have a practically identical aspect. Often the Drift is banked up against the Bunter escarpment, at other times it caps the high ground. The Boulder-clay, in like manner, frequently lies on the clay soil of the Permian, and has apparently been formed from it. The red marl of Bulwell often contains Bunter pebbles for some depth, showing that it has probably been affected by the ice movement. Mr. Sherlock.

Further east around Southwell no Drift has as yet been met with.

RECENT.

The river terraces of the Trent and Derwent, mentioned in the Summary for 1901 and 1902, extend up the Derwent valley through the town of Derby as far as Markeaton. Mr. Fox-Strangways.

Some of these gravels have been considered by Mr. Deeley to be of late glacial age,* and they very probably belong to the High

* *Quart. Journ. Geol. Soc.*, Vol. xlii., p. 477.

Level Valley Gravels described in the country to the south, although it is very difficult to separate them from the true river terraces.

Mr. Sherlock. The small river Leen is remarkable for an extensive plain of river gravel, which occurs between Papplewich and Goosedale Bog. This plain is three-quarters of a mile wide, and an arm of it extends up the valley east of the village as far as Barrack Farm.

ECONOMIC GEOLOGY.

Mr. Fox-Strangways. The chief mineral wealth of the district lies undoubtedly in the numerous coal and ironstone seams that have been so extensively worked from their outcrop a little east of the Derwent valley to their overlap by the Permian and Triassic rocks on the east of the Erewash valley, and are now being followed further and further to the east beneath these overlying measures.

In former times the next most important mineral was the lead from the Carboniferous Limestone, which has been so extensively worked in the neighbourhood of Wirksworth, and at Crich; but this industry has now entirely died out, the mines having been closed for some fifteen years or so.

The Coal-measure clays and marls furnish abundant and valuable material for sanitary pipes, bricks, etc., and are worked in several localities, but chiefly in the measures below the Top Hard Coal. The red Permian marls are extensively quarried around Bulwell for bricks and flower pots.

The Magnesian Limestone in the same neighbourhood has for long furnished an abundant supply of building stone, and certain bands are said to produce a good supply of hydraulic lime.

The Drift sands near the Portland Collieries are in much request for the Butterley Ironworks; the gravelly beds at Friezeland yield a small supply of gravel.

The Keuper Marls are worked at Derby and other places for brickmaking, but many of the old pits are now closed, the tendency of the trade being to concentrate in a few large works.

Excellent water is pumped from the Bunter Sandstone at Fairfield for the supply of the towns of Southwell and Newark.

2. Southern District—Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher.
Mr. George Barrow.
Mr. J. B. Hill.
Mr. D. A. MacAlister.
Mr. J. B. Scrivenor, M.A.
} Geologists.

Mr. Reid. The re-survey of Cornwall has now been connected over various parts of the area; but the true relations between the rocks of the south-western and those of the north-eastern district still remain uncertain. These questions will, it is hoped, be cleared up when

the remainder of the intermediate area, and the country around Gorran Haven, have been minutely examined. Under these circumstances it will be most convenient to deal with each finished area separately. Mr. Reid.

NEWQUAY AREA.

Palæozoic.—The mapping of the country around Newquay has now been completed. It is found that the anticlinal axis, described in the last Summary as bringing up Lower Old Red Sandstone in Watergate Bay, dips eastward, so that these rocks entirely disappear before St. Columb Major is reached, and the overlying marine Lower Devonian strata on either side sweep round, to join just at the edge of the map. This continuity of the Meadfoot (or Newquay) series across the anticlinal axis is also demonstrated by the exact resemblance of the strata, for near St. Mawgan calcareous shales and thin limestones, identical with those of St. Columb Porth, can be seen, and these are succeeded in either area by non-calcareous and harder slaty rocks.

Towards the eastern border of the Newquay area, near Trebudannon and Crugoes, sheets of greenstone, or more probably one sheet repeated by folding, become conspicuous, though the exact horizon on which this occurs is not quite clear. The greenstone may well correspond with the thinner sills of Kelsey Head and St. Pirans, for similar rocks have been traced inland at various intermediate points, first striking east-south-east, then due east, and afterwards reappearing towards the north-east, as these strata, like the older ones, sweep round the nose of the Watergate anticline.

Between Mawgan Porth and Bedruthan the Meadfoot Series is succeeded by unfossiliferous hard sandstones, grits and sandy shales, among which are bands of tough quartzite. These rocks (the Staddon Grits) strike east-south-east, passing north of St. Columb Major, beyond which point they have not yet been mapped. They are succeeded by the grey, sooty, or micaceous decalcified slates of Bedruthan, certain seams of which are full of fossils, in the shape of hollow moulds, flattened impressions, or pyritous casts. Crinoids and the anomalous *Pteroconus mirus* are the most abundant fossils in these slates.

On the south side of the anticlinal axis sandstones and sandy shales also occur, and have been traced by Mr. Scrivenor from Perranporth through St. Allen to Ladock, where they become coarser. Their strike is approximately east and west; towards the south they connect with the Portscatho Series mapped by Mr. Hill. Mr. Scriven

Whether the sandstones in the southern part of the Newquay map are of the same age as those in the northern, must remain uncertain till more of the area to the east has been examined. Thus far, unfortunately, they have proved to be entirely devoid of fossils. Mr. Reid.

Dykes.—The mapping of the igneous dykes in the Newquay area has shown that the exceptional north and south elvan (quartz-porphyry) of Watergate Bay is probably connected by a broken

. Reid. curved dyke with a dyke running east-south-east through Retyn to Blue Anchor. The continuity, however, is not absolute; but this and other evidence seem to suggest a close connection between the various elvans, whatever be their trend at the surface.

A north-north-east and south-south-west dyke of extremely rotten minette (once extensively dug for manure), which runs from Mountjoy to the railway at Coswarth, is interesting as carrying the mica-traps into a new area. This dyke may cross the elvan of Retyn, above alluded to, and thus prove conclusively their relative ages; but the fields where the dykes should intersect are now meadow land, in which no rock is visible. None of the Cornish minette dykes has yet been proved to cut an elvan, though there is little doubt that those near Newquay at any rate are of later date.

ST. AUSTELL AREA.

r. Ussher. In the St. Austell area, which lies to the east of that just described, the large granite mass of St. Austell is included, and the country on the north and on the south of this granite has not yet been mapped in detail.

Palæozoic.—Mr. Ussher has now traced the Lower Devonian rocks from the areas previously surveyed by him westward to St. Austell. His investigations have made it practically certain that the Dartmouth Slates (the lowest known Devonian group) are cut off by north and south faults in the district south of Lostwithiel. They do not reach the eastern margin of the St. Austell granite, nor do they appear to the south of it in the districts surveyed.

The rocks above the Dartmouth Slates in the St. Austell area belong to the Meadfoot group, with the exception of those between Pentuan and Sticker, where grits and banded argillaceous and arenaceous rocks, perhaps belonging to another series, come on. It is necessary to bear in mind the variable character of the Meadfoot group, both as regards the associations of grit with the slates, and as regards the nature and persistence of the fossiliferous beds. The occurrence of grits in the Dartmouth Slates, or at their boundary and in the dark slates above, is well seen near Fowey; but it is seldom possible to map out synclines of the basement beds of the Meadfoot group in the Dartmouth slate area. This has been done in one place north of Fowey, where the dark slates contain a mass of diabase and many intercalated beds of grit.

The basement beds of the Meadfoot series are succeeded by the fossiliferous beds of Pencarrow Head, consisting of irregular siliceo-calcareous slates, in which both cleavage and bedding are well defined. These strata, but sparingly fossiliferous, are exceptionally developed towards Polruan, where they form fine craggy heights. They are well shown on the coast south of Fowey, to Readymoney; and are followed by dark grey calcareous slates of the Newquay type. These latter give place to another series of dark slates, with occasional phosphatic nodules, towards Coombe Hawne; the dark slates contain masses of pale-green igneous rock.

Fossiliferous rocks like those of Pencarrow Head and Fowey have been traced to Polkerris, and also on the north side of the Dartmouth slate anticline, east of the River Fowey, throughout the Lerryn district. Faults cut off this fossiliferous horizon on the west, bringing the fossiliferous strata against the Dartmouth slates, and the higher sparingly fossiliferous dark slates against the fossiliferous strata. Mr. Ussher

There can be little doubt that the cliffs from Par by Charlestown and Duporth to the Black Head are composed of the same dark slate series with occasional igneous rocks; though here and there anticlines bring up the interlaminated calcareous slates. Round the St. Austell granite the dark slate series trends westward. The general absence of fossils in the strata surrounding the granite is readily explicable if we refer them to the higher parts of the Meadfoot group, which lie between the top of the fossiliferous horizon of Looe and Newquay and the Staddon Grits.

From the displacement of igneous bands, from the frequent appearance of nearly horizontal schistosity presented by the slates, which are in most cases cut into irregular segments by small thrusts or slides, and from the recurrence of interlaminated beds apparently belonging to the same horizon, the cliff sections of St. Austell Bay suggest the repetition of the same series of rocks by small sharp zig-zag folds, obliterated by contortion-slides or thrusts, producing the effect of more or less horizontal bedding.

The zone of contact alteration in the slates between St. Austell and St. Blazey varies in breadth from half to three-quarters of a mile; but south and south-east of St. Austell its outer limit is purely conjectural. Hornstones of the peculiar banded and porcellanous type, of Peak Hill and Brent in Devonshire, are conspicuous near the granite at Lostwithiel and south of Lanhydrock, at Rosevanion (east of St. Columb Major) and at Fraddon; but have not been met with along the southern margin of the granite.

Greenstones.—The behaviour of the greenstones around St. Austell differs greatly from that represented on the old map. Instead of narrow continuous bands, the rocks occur as isolated masses, distributed in a manner according with contemporaneous origin, as suggested by J. A. Phillips. They are ophitic diabases, usually much altered.

Granite.—The southern border of the St. Austell granite is for the most part coarsely porphyritic, though on the whole less so than the Dartmoor and Cheesewring rock. It is usually much decomposed, but occurs in three conditions—hard but irregularly disintegrated; decomposed, with the felspar insufficiently kaolinized to be worked as china clay; and entirely decomposed, the felspathic constituents being wholly kaolinized. It is quite impossible, however, to separate the solid granite by boundary lines on the map.

To the eye the partly kaolinized granite is not easily distinguishable from the china-clay stuff; moreover, solid jointed granite is often found in a basin-shaped mass resting on the china-clay material;

Mr. Ussher. or irregular walls of solid or partly decomposed granite may ramify through the kaolinized granite. In none of the pits, in the area around St. Austell yet surveyed, has solid granite been found to underlie kaolinized granite, and, as a rule, the clay improves with depth.

Quartz-schorl veinstones, often of a very bunchy character, occur in variable proportion in the granite. When these are abundant in the china-clay pits the clay in their vicinity takes a bluish tinge and is suitable for potting; the white clay used for many other purposes does not burn sufficiently hard. The veinstones are locally called lodes or stent; they occasionally carry tin. They are very irregular, but most frequently dip northward and run east and west.

Between Pentuan and the St. Austell granite, seven elvan courses have been detected; but these do not appear continuously at the surface, as shown on the old map. To be able to trace them at the surface for nearly a mile, as in the case of the "Pentuan stone" (the elvan on the north of Pentuan), is quite exceptional. They are white or greyish rocks, either quartz-porphyries or non-porphyritic, and are like those seen near the western edge of the granite.

Economics.—As building stone, the elvans, particularly the Pentuan stone, furnish the best materials in the district; they are found when well selected to harden with exposure. The Pentuan stone quarries are disused; the dyke on reaching the coast branches laterally northward and is exposed in a nearly horizontal band, sometimes from 9 to 12 feet thick, for a quarter of a mile in the cliff. Working on the coast was discontinued owing to the danger of undermining the slates. Elvans have also been quarried at various other places in this area.

The sounder parts of the granite have also been used locally as building stone, especially for the engine-houses of the old mines. Quarries have been opened in the Devonian slates or shales, where the planes are sufficiently coherent to yield fair-sized blocks. This stone, as elsewhere, is used for building purposes throughout the district, but can hardly be considered a very desirable material.

The diabase quarries near St. Mewan furnish the local authorities with excellent road metal, which is broken up by stone crushers; while the well-known Duporth igneous rock * is admirably adapted for ornamental purposes, etc.

Mines.—Of the numerous tin and copper mines in the area surveyed south and east of St. Austell four only are now working, viz.: Polmear, near Charlestown (copper, tin, and zinc-blende), and Commerce, Venton Whin, and Bucka Pit (tin). At Wheal Menear and Polgooth (tin) operations were also being carried on in 1903. Most of the mines are well outside the limits of contact alteration. The Wheal Eliza and Par Consols lodes are partly in, partly outside, the altered zone; whilst those of Wheal Menear and Boscoppa are well within it.

* *See* J. H. Collins, *Min. Mag.*, vol. i., p. 222.

The direction of the tin and copper lodes generally approximates to east and west. The underlie or dip is towards the north, and is sometimes, as in New Boscundle lode, said to be at so low an angle as to be nearly flat. Mr. Usshe

There is scarcely a valley in the St. Austell district which has not been extensively streamed for tin; but these works are now abandoned. The amount of detritus thus artificially produced is considerable, and it is largely augmented by the sand-refuse from the clay-works, which after exceptional rain is carried down by the swollen streams and spread over the low ground, where precautions have not been taken to prevent flooding. Much damage was thus done in the Pentuan Valley by the floods of last October.

In order to prevent washings from the mines and clay works from having access to Par Harbour, an adit was constructed to deflect the drainage of the valley at Pembroke House (about a mile west of Par Harbour) and give it a direct outlet to the sea at Shorthorn beach, where Mr. Abelspies states that a considerable thickness of material has thus been deposited.

FALMOUTH AREA.

The completion by Mr. J. B. Hill of the Truro Sheet (352) during the past season has brought to light no features of interest as regards the stratigraphy of the region that have not been touched upon in former reports. Moreover as the sheet explanation will be written immediately the summary of the year's work is necessarily concise. Mr. J. B. Hill.

Palæozoic.—The sedimentaries consist of the Mylor, Falmouth and Portscatho series, the latter of which is succeeded eastward from Pendower in Gerrans Bay by a small portion of the Veryan series.

The Portscatho series extends from Gerrans Bay on the east to Porth Towan on the north-west.

The Falmouth beds which succeed them occupy a large belt of country between Truro and Chacewater, but the paucity of sections prevents the drawing of accurate boundaries. From the vicinity of Chacewater Station westward to Parsley, the Falmouth beds have not been differentiated, probably due to their typical characteristics being feebly developed, and to the obscurity of the sections.

The Mylor series which occupies the south-western districts encloses the granite masses of Carn Menelez, Carn Marth, and Carn Brea, the greenstones, together with the bulk of the elvans. This series contains, moreover, by far the larger portion of the mineral lodes of the area.

Greenstones.—In former reports greenstones have been described flanking the granite between Falmouth and Gwennap. In the neighbourhood of Camborne, greenstone again occurs, forming large masses, the boundaries of which can only be approximately drawn. The greenstone at Camborne differs from the normal type formerly described by the presence of garnetiferous veins, and the prevalence of a very fine-grained matrix.* In mass

* *See* Appendix II. by Dr. Flett, p. 153.

J. B. II. they are also less compact, are more banded, and have suffered more from folding and shearing. Not only is the greenstone very fine in grain, but the presence of abundant veining is characteristic. The veins are extremely irregular, probably the result of contortion, and are filled with massive garnet. The veins, which vary in thickness from 2 or 3 inches down to the smallest threads, are sometimes so numerous as to account for half the bulk of the rock. They are bounded by very pale greenish margins in sharp contrast to the dark colour of the greenstone. Moreover, pale veins of this nature occur without garnet. In the garnetiferous veins the mineral usually occurs massive, but sometimes shows well-defined crystallisation. The enclosing rock consists of acicular green hornblende in strings and bundles in a matrix of clear granular felspar, so fine grained as to form in some places almost a crypto-crystalline mosaic. Besides small grains of iron oxide, occasionally converted into sphene, clear brown biotite and chlorite are present, but no garnet.

At Werth farm a greenstone of this type was veined with green hornblende, quartz, and clear greenish pyroxene. In a quarry near Tuckingmill Gas Works, a garnetiferous patch in the greenstone consists of pink isotropic garnet often intergrown with epidote and never distinctly idiomorphic. It is mixed with pale green pyroxene, epidote, chlorite, sphene and a colourless micaceous mineral after plagioclase felspar, and calcite also occurs. The minerals have evidently taken their present crystalline form subsequent to the shearing of the greenstone.

Another mass of sheared and banded greenstone occurs half a mile north-east of Camborne Station. Although garnetiferous veins are absent, small veinlets of hornblende and of epidote are present. It moreover contains much clear pale green pyroxene, generally without distinctive form, which together with the biotite may be ascribed to the contact action of the adjoining granite, small veins of which are actually visible in the greenstone.

Although parts of their matrix closely approach that of some of the normal sheared greenstones, it is evident that they were originally richer in lime, which contact metamorphism has converted into calc silicates. Whether like the normal greenstones they were intrusive, is not clear. The fine banding and somewhat uniform fine-grained matrix may even suggest a volcanic ash or mud. Microscopic examination, however, affords no indication of clastic structure, nor have the presence of undoubted ash-beds or even lavas been demonstrated in this part of Cornwall.

The greenstone exposed in the large quarry at Tuckingmill is of the normal type, while another mass which flanks the granite in the Cober Valley in the parish of Wendron is of similar character, but parts of it are rich in biotite due to contact action of the granite.

Granite.—The Carn Menelez granite, which has been described in former reports, while presenting the same general type throughout, nevertheless exhibits local deviation both as regards composition and uneven consolidation. Speaking generally the eastern margin

of that mass is not only of finer texture but is perceptibly richer in biotite—these characters mark also a greater part of the southern margin. On the south-west and west, however, there is no perceptible difference as regards texture, but it continues to be rich in biotite, often almost to the entire exclusion of white mica. Mr J. B. Hill.

Contemporaneous veins of fine-grained granite or aplite are common over the entire mass. They are less abundant, however, in the eastern portion, but are extremely numerous in the central district, while in the west two areas of fine-grained granite occupy tracts sufficiently extensive to be separately mapped. One of these, exceeding a square mile, occurs between Bolitho and Boswyn; the other forms a lobe, about a quarter of a square mile, which protrudes from the margin of the granite at Praze. The latter is a fine-grained biotite-tourmaline-granite occurring amongst coarse granite of similar composition, with which its marginal relations are obscure.

The mass between Bolitho and Boswyn exhibits more exposures. Over a large part of its area the fine texture is fairly uniform, often approaching that of an elvan, but veins of coarser granite are of frequent occurrence, while at times the fine granite itself may contain idiomorphic felspars as large as an inch. The marginal relations are usually obscure, but occasionally the fine granite veins the coarser normal type. At Crowan Beacon, however, the passage of the normal granite into the fine-grained type is seen. Here the former gives rise to tors with rude stratiform structure which are absent in the area of the latter. It passes first into a coarsely porphyritic granite, the porphyritic constituents being identical with the individual crystals of the normal rock, but lying in a ground mass of finer material. The porphyritic individuals, however, both felspar and quartz are idiomorphic, so that with a sufficiently fine ground mass we reach a rock indistinguishable from some of the elvans.

The western portion of the Carn Menelez granite between Trannack and Praze is flanked by small sills of fine-grained granite and greisen, in some of which tourmaline is present. This mineral, however, as in the granite, is of sporadic occurrence, masses rich in that mineral being contiguous to zones in which it has not been detected. A sill half a mile north-east of Sithney Green is a porphyritic biotite granite in which tourmaline is rare. Another sill seen in the railway cutting a quarter of a mile west of Truthall is a tourmaline muscovite granite so sheared that the quartz and felspar are often granulitic, with muscovites bent and dragged out. It is highly quartzose and is practically a schorlaceous greisen. A fine-grained greisen about 6 feet wide occurs one third of a mile west-north-west of Truthall.

The tourmaline in these marginal sills is both of the blue and brown varieties. The sills themselves often closely resemble the finer-grained portions of the main mass, and no doubt both represent the final stages of consolidation. In some portions of the main granite, however, as at Croft Michell, the main part of the ground mass is micro-granitic with an exceptionally larger amount of micropegmatite and the rock more properly falls under the category of a quartz porphyry.

Mr. J. B. Hill.

In the fine-grained porphyritic muscovite biotite granite of Crowan Beacon topaz is a common constituent, while an aplite in the granite near Lanner contains green tourmaline, a variety exceptional in Cornwall.

The Carn Brea granite is of similar type to the Carn Menelez mass with which mining operations have demonstrated its subterranean continuation.

The Carn Marth granite is of similar composition, but probably richer in tourmaline. Moreover the grain of the rock is finer and the general textural arrangement over its entire mass suggests an independent intrusion from a common reservoir rather than its direct connection with that of Carn Menelez. Its shape, moreover, supports this hypothesis,

All these granite masses are pierced by elvans, which have also cut some of the greenstones, while the latter are also invaded occasionally by fine-grained granite.

Building materials and road metal.—The granite of Carn Marth is extensively quarried. It is inferior in quality to the granite of Mabe and Constantine, and does not yield such large blocks. It has been extensively used for building-purposes in the districts of Lanner and Redruth. The greenstones of Tuckingmill and Trannack and the elvans have been mainly utilised for macadam, but these rocks have often been supplemented by granite and the materials from the spoil heaps.

Near St. Day a brick-factory furnishes an output of over a million bricks annually. The granite is decomposed for a depth of about 50 feet, and was formerly used for china-clay, but was not sufficiently good to compete for this purpose with the superior clays of the St. Austell district. On account of the gritty nature of the clay the individual bricks are cut by hand. The bricks produced from this decomposing granite have smooth faces, but the edges are imperfect.

MINING.

Mr. Maclister.

The recent increased demand for tin has led to the opening up of some of the old Cornish tin mines. Some of the old "burrows" or "tips," the refuse of former mining operations, have been considered valuable enough for treatment by modern ore-dressing appliances. In some cases the old heaps of "sands" or "tailings" from which tin was supposed to have been all extracted, can be treated economically at the present time. The Frue Vanners, introduced some years ago, for the preliminary concentration of the pulp, yield concentrates which may contain as much as 70 per cent. of black tin (1,736 lbs. of cassiterite per ton). The degree of concentration varies, however, from 30 per cent. to 70 per cent. (748 to 1,736 lbs. of cassiterite per ton) according to the amount of accompanying heavy sulphides, or fineness of the tin in the ore treated. The concentrates are then calcined, and undergo further

concentration. The "tailings" from the vanners containing, say, ·12 per cent. (2½ to 3 lbs. of black tin per ton) and are concentrated by the old methods. Mr. Mac-Alister.

Vertical distribution of the commercially valuable ores in the Camborne Lodes.—The lodes with a general bearing of E. 30° N. are parallel to the margin of the Carn Brea granite, and the information can be generalised for each series of lodes.

The South Crofty Series of lodes includes those lodes in Wheal Tehidy (on the east), Wheal Agar, East Pool, South Crofty, North Crofty, East Crofty, South Roskear, and Crane (on the west), situated along a line about half a mile north of the margin of the granite.

The average depth at which granite was first encountered in the principal mines in the foregoing list, is about 170 fms. below the surface of the killas. On the west it is greater, and on the east less.

The lodes are characterised by good gossans. The copper ores were especially abundant from the higher levels (where they were oxidised) to varying depths in the different mines, but, generally speaking, 150 fms. below the surface marks the limit of occurrence. in depth. Tin ore was worked from 80 fms above the surface of the granite to the deep workings below. Wolfram was abundant (especially in East Pool) from 10 fms. above the granite surface to 10 fms. below, but in smaller quantities it had a wider range. Other minerals, occurring principally in the higher levels, include ores of cobalt, zinc, and uranium. Mispickel was a common ore.

The Dolcoath Series of lodes includes those lodes in Barncoose (on the east), Wheal Druid, southern part of East Pool sett, Carn Brea, Tincroft, Cook's Kitchen, New Cook's Kitchen, Dolcoath, Camborne Consols, Camborne Vean and West Stray Park, etc. (on the west). The principal mines are situated along the margin of the Carn Brea Granite. The main lodes first encounter the granite at about 100 to 130 fms. below the surface of the killas (on the west of Dolcoath it is over 220 fms. below). The main lodes all have good gossans. The copper ores in Cook's Kitchen and Dolcoath were very rich down to about 200 fms. below the surface, but in the former mine copper continued to occur down to 360 fms. below the surface, but was not so valuable in depth. Tin ore in Dolcoath was especially abundant from 180 fms. below the surface to near the bottom of the mine, which is now down to the 485 fm. level, where the lode is 42 feet wide and contains about 25 lbs. of black tin per ton. In Carn Brea the lodes were very poor in tin in the deep levels, although tin occurred in greater or less quantity right up to the surface before it was worked out. Exceptional ores for this district were those of silver, which occurred in the "Silver Course Lode" in Dolcoath at a comparatively shallow level.

In the Great Condurrow Series, situated further south and consequently entirely in granite, the tin and copper ores were mixed, but copper was not abundant below the 200 fm. level. Tin ore occurred in the lodes from the surface downwards.

. Mac-
ister.

The Great Flat Lode Series includes Wheal Basset (and other mines on the east), West Basset, South Frances, Wheal Frances, West Frances, Wheal Grenville, South Condurrow, South Tolcarne, and several trials (on the west). On the west the Flat Lode series is practically wholly in granite, and lies in a valley situated between the Carn Menelez Granite and its Carn Brea outlier. In going eastwards the granite is found at a greater depth, and the Flat Lode itself passes out of the granite into the killas and lies parallel to, and not far removed from, the granite surface. The more or less vertical lodes which intersect the Great Flat Lode pass into the killas eastward. The Flat Lode has never contained much copper, but in South Condurrow and Wheal Basset copper has been found in small quantities (as "native," oxidised, and sulphide ores) to 80 fms. below the surface. Generally speaking, it is a wide lode of low grade tin ore. The more or less vertical lodes which intersect the Great Flat Lode were mainly copper. In Wheal Basset these lodes, eight or nine in number, contain copper to a depth of 150 fms. and were poor below, although still in killas at that depth. On the west, where the vertical lodes are in granite, they are not copper-bearing to such depths.

Levant Mine (St. Just).—The operations are almost entirely confined to the parts of the lodes which intersect the greenstone sill fringing the coast. The granite plunges beneath the killas in a north-westerly direction at an angle of 50°. Beyond the killas (a thickness of over 100 fms.) the sill of greenstone underlies in the same direction as and approximately parallel to the surface of the granite. The lodes striking from the granite in a north-westerly direction cut across the granite and the greenstone approximately at right angles. Mining operations, although at present almost entirely confined to the greenstone "country," do not appear to have revealed its outer boundary. The lodes are unproductive or very poor in the granite for both tin and copper ores, but they get more productive in passing from that rock into the killas and greenstone beyond. Although there seems no reason for supposing that the greenstone in any way contributed in localising the productive belt, it is worth noticing that the ore ground seems to be persistently associated with that rock from quite near the surface to the deep levels (338 fm. level). For a great distance the ore ground is, practically speaking, coincident with the greenstone, but it should be regarded as bearing a definite relation to the surface of the granite, and the ore ground actually removed in mining operations is seen to be roughly parallel to it.

In the St. Just district there is a variety of schorl rock locally known as "Ramp." A common type is a drusy aggregate of quartz and granular and acicular tourmaline crystals, the texture varying from compact to coarse. Formerly, in East Levant Mine, there was evidence that at least one tin lode intersected a course of "ramp" which thus appears to be an older formation.

DRIFT.

Mr. Reid.

The mapping of the drift in Cornwall has given a great deal of trouble, for it is difficult to decide how to treat the masses of decayed rock which form so striking a characteristic of the county. Any perfectly consistent treatment seems hopeless, for away from the coast it is quite impossible to say where rock decayed in places ceases and where true drift begins. What has finally been done is this: all masses of head or rubble-drift filling old bays have been mapped; as have all gravels and tin-stream deposits (except a few, which are nothing but lode-material concentrated on the spot). Besides these sheets, however, thick masses of rotten and sometimes of transported rock rest on nearly every flat shelf, whatever may be its elevation above sea or valley. Attempts were made to map these; but they had to be given up as hopeless, for none of the sheets have definite limits, and it was found impossible to distinguish between deep soils and sheets of drift on these platforms. Characteristic areas of this sort will be seen around St. Agnes' Beacon, which seems to be nearly surrounded by a ring of drift with no clear outer limit, the drift resting on the Pliocene platform. Another will be found at St. Erth, where a considerable thickness of head is seen to overlie the Pliocene bede, but was not mapped because of its indefinite boundaries.

SCILLY ISLANDS.

Mr. G. Barrow.

The survey of all of the larger, and most of the smaller, islands has been completed. The weather was, however, too rough to enable the small outlying rocks to the west to be examined.

Palæozoic.—The result of the survey confirms in the main the observation of previous workers that the islands are practically composed entirely of granite. So far, only one minute dyke-like inclusion of altered sediment has been met with, but this, as might be supposed, is highly crystalline.

Granite.—The granite, from the schorl present and the numerous lines of a greisen alteration, is clearly of the same age as most of the large masses on the mainland, and like some of them has a central core of finer material, though the line separating the finer from the coarser granite is at times very ill-defined. The outer mass is coarsely crystalline with abundant twinned crystals of orthoclase averaging about an inch long. The detailed account of its structure will be given when sections have been made from the specimens collected. The lines of greisen alteration are exceptionally well seen in many of the smaller islands, owing to the large proportion of coast line. They are singularly parallel, trending roughly East-North-East, and occur as a rule in groups, which are very abundant but unevenly distributed. They are clearly seen to be a series of minute cracks, and the alteration extends to a distance of two to six inches from each side of the crack. This is often filled with

Mr. G. Barrow.

quartz, quartz-schorl, or more rarely with almost pure schorl. The thickness of this infilling material is usually small. In a few rare cases coarse pegmatite has been met with in the cracks, but whether it is exactly of the same age as the quartz-schorl material is not clear; it appears almost too fresh and unaltered to be so.

A series of specimens of the greisen has been collected for further examination but there is clearly no serious amount of mineral ore associated with them. Traces of old workings have been met with along these lines at the north end of Tresco, and though little ore was obtained, as shown by their small size, some must have been found or there would not have been so many trials made. This is an interesting point, for these trials are almost in a line with the little dyke-like inclusion of sedimentary material already referred to. Evidence will be given at a future date to show that the north end of the islands as a whole probably corresponds approximately to the outer edge of the granite, and the oncoming of a small quantity of mineral ore is exactly what would be expected from the experience gained on the mainland, where the greisen is associated with ores chiefly at the margin of the granite.

Another series of cracks or joints is also present which trends roughly north and south, and, like the greisen lines, give rise to hollows in the granite. The form of many of the smaller islands is dependent on these intersecting sets of parallel hollows. It may be described as a series of quadrangular nobs of harder granite projecting above the softer broken material. Obviously only the latter can be cultivated, and thus they have an important bearing on the industry of the islands which is essentially agricultural or horticultural. In the larger islands, there is an old plateau, roughly, 100 feet above sea-level, in which this conformation of the ground is largely lost, though even here there seems a deeper soil in some parts than others, probably connected with these lines of weakness and decomposition.

Drift.—It has long been known that flint and other far-transported pebbles occur in Scilly. These are first met with at the north-east end of St. Martin's, the highest point of all the islands. Here they are exceptionally abundant, but as we descend to the south they suddenly cease. In a westerly direction they continue to sea level, and are found in a clay matrix in the first little bay on the north coast of the island. This mode of occurrence is quite exceptional, and nowhere else are they so found. As a rule they are either loose or embedded in a curious hard ferruginous sandy clay, to which the name of Iron-cement may be temporarily applied. It occurs on all the islands, but its exact mode of origin has not been ascertained at present. Either free or embedded in this cement, the pebbles occur across the projecting northern ends of all the islands, ascending in all cases to the top of the ridge and descending on the other side. That is to say, their distribution is at right angles to the contouring of the ground, and it is this mode of occurrence, combined with

their persistent ending off a little to the south of the projecting end of each island, that is so difficult to account for. Mr. G. Barrow.

When the general trend of the islands turns south, so as to face the west, these pebbles follow the change of the coast line, and are found on Sampson, Annet and the south-west point of St. Agnes. By far the most abundant pebbles are chalk flints and next in number to these are reddish sandstone, perhaps from Hayle or St. Agnes. The fuller account of them will be given after sections have been made and examined.

On the east side of White Island a four-inch pebble of the sandstone was observed firmly embedded in the iron-cement a little above the ordinary high tide mark. This was seen to be well scratched, and the scratches appeared identical with those of glacial action. The stone was dug out and the buried face has been washed; it proves also to be facetted and ice-scratched, so that, however it reached the position where it was found, it is clearly a true, though small, glacially scratched boulder. This is the most southerly striated erratic yet found; it occurs in latitude 49° 59′, or nearly a degree south of that found near Selsey Bill.

3.—South Wales District—Carmarthenshire and Pembrokeshire.

Mr. Aubrey Strahan, M.A., F.R.S., District Geologist.
Mr. B. S. N. Wilkinson.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A.
Mr. O. T. Jones, B.A., B.Sc.
} Geologists.

The South Wales Coal-field, though possibly continuous under the sea, is separated into two portions by Carmarthen Bay, the main portion terminating near Kidwelly, while the smaller portion extends from Carmarthen Bay westwards across Pembrokeshire. Between the two, the coast for about ten miles is formed of Lower Carboniferous rocks and Old Red Sandstone. The outcrop of the Old Red Sandstone is wide, partly through undulations and partly as a consequence of large strike-faults.

The work of the past year has lain in the Ordovician rocks in the neighbourhood of Carmarthen, in the Old Red Sandstone south and south-west of that town, and in the Carboniferous rocks of the neighbourhood of Kidwelly, at the western end of the main portion of the Coal Field, the examination of which is on the point of completion. The surveying of the Pembrokeshire portion has been commenced at its eastern extremity.

ORDOVICIAN.

essrs. Can-ill and homas.

The Silurian rocks having been overstepped by the Old Red Sandstone near Middleton Hall,* the section of the older strata commences in the Ordovician group near Carmarthen.

The succession is practically identical with that established in the Haverfordwest district by Messrs. Marr and Roberts,† and in the Carmarthen district by the Misses Crossfield and Skeat.‡ The following table gives in descending order the subdivisions which have been found to occur in the area surveyed during 1903 :—

Redhill Beds.—Blue-grey mudstones with crinoids and corals.

Sholeshook and Robeston Wathen Limestones.—Dark thin-bedded limestones, with brachiopods and trilobites (*Cybele verrucosa*, etc.).

Dicranograptus Shales.—Intensely black shales, with *Diplograptidæ*, *Climacograptidæ* and *Dicranograptus*. (The Lower Bala Beds of Hicks).

Llandilo Limestones.—Dark impure limestones, with *Asaphus tyrannus*, *Ogygia Buchii*, etc. These correspond to the upper part of the Llandilo Flags of Llandilo. The lower part of the flags is represented by the next lower division.

Didymograptus Murchisoni Shales.—(Upper Llanvirn of Hicks).

Didymograptus bifidus Shales.—(Lower Llanvirn of Hicks).

Ogygia marginata Beds.—(Arenig of Crossfield and Skeat).

Peltura punctata Beds.—(Tremadoc of Crossfield and Skeat).

r. Thomas.

Peltura punctata and *Ogygia marginata eds.*—This series of pebbly grits, conglomerates, and mudstones which first makes its appearance to the west of Llanarthney and lies between the River Towy and the Old Red Sandstone, takes the form of a much folded and faulted anticline with an easterly pitch. On fossil and structural evidence it is proved to include rocks of Tremadoc and Arenig age, *Ogygia marginata* being abundant at some localities and *Peltura punctata* at others. The blue mudstones of Pen-y-banc-isaf have yielded in their upper part many specimens of *Ogygia marginata*, while lower in the succession they yield only *Peltura punctata*, an *Orthoceras*, *Theca*, and a few lamellibranchs. The above-mentioned series is evidently of the same age and yields the same fossils as that first described by the Misses Crossfield and Skeat in the district to the west.§

To the west these rocks are well-developed in the neighbourhood of Cwm-ffrwd, in the valleys of the Ffrwd, Glasdwr, and Pibwr, and are abundantly fossiliferous.

Didymograptus bifidus Shales.—Shales containing this characteristic fossil with other species rest upon and gradually pass down into the Arenig mudstones with *Ogygia marginata* which occur to the

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* Summary of Progress for 1902, p. 41.

† *Quart. Journ. Geol. Soc.*, vol. xli., p. 476 (1885).

‡ *Ibid.*, lii., p. 529 (1896).

§ The area mapped in the neighbourhood of Carmarthen includes the district described by the Misses Crossfield and Skeat (*op. cit.*), and their paper has been of great assistance especially in regard to the chief fossil localities. It is with great pleasure that we find the work of the Survey has caused very few alterations to be made in the geological lines shown in their sketch-map, and has in every way testified to the excellence of their work.

south of the Swansea Road, near Pen-y-Morfa. They attain by far their greatest development on the north side of the River Towy, around the faulted outlier of *D. Murchisoni* Shales which forms Merlin's Hill. Thence they continue in a westerly direction as far as the survey has been completed. They contain well-marked beds of banded ashes in the neighbourhood of Bryn-Myrddin, and pass in a northerly direction upwards without break into the more flaggy *D. Murchisoni* Shales. They are well-exposed in a stream below the ash-beds of Pen-y-graig and Cwm to the north of Abergwili. Graptolites in magnificent preservation abound, but occur only in quantity in thin bands. Mr. Thomas

Didymograptus Murchisoni Shales.—The Llandilo Limestones become less frequent westwards, as mentioned in the *Summary of Progress* for 1902 (p. 41). The last of them in this neighbourhood occurs on the south flank of Merlin's Hill. It contains the usual Llandilo Flag fossils in a quarry at Felin-wen. In the immediate neighbourhood of Carmarthen the *D. Murchisoni* Shales are well developed on Penlan and Tre-Vaughan Hills. Occasionally they include beds of orange-coloured rottenstone of similar character to that met with in the Llandilo Flags of the Llandilo district. The shales contain *Didymograptus Murchisoni, D. geminus, Diplograptus, Siphonotreta micula*, and occasionally some of the Llandilo Flag trilobites. To the north of the area undergoing examination these shales pass up into black shales which contain *Diplograptus*, forming part of the *Dicranograptus Shales.*

No true igneous rocks have as yet been met with on this horizon, but that eruptions were taking place at no great distance is proved by the presence of bedded ashes and coarse ashy grits.

The Didymograptus Shales are well-developed in Cliff Lane and other sections west of Lower St. Clears, and have yielded *Aeglina binodosa*, with graptolites of the *D. bifidus* group. In this district limestones of Llandilo Flag age reappear, and a band which has been quarried at Pant Dwfn and at Lower Court near St. Clears appears to be a thin calcareous development of the highest of the *Didymograptus* Shales; it has yielded characteristic Llandilo forms, such as *Asaphus tyrannus* and *Ogygia Buchii*, and is often rich in *Beyrichia complicata.* Mr. Cantrill.

Dicranograptus Shales.—These beds are best exposed on the north side of the River Towy and run, with a strike of W.15°S. and a general northerly dip, to the north of Dryslwyn Castle, and thence across the Dulais Valley to Llanegwad and Cincoed, where they are concealed by the alluvium of the Towy. A small quarry in the village of Nantgaredig, 100 yards north of Ty-newydd Farm, shows black limestone passing upwards into black graptolitic shales. This limestone is succeeded at a distance of 150 yards to the south by another band of similar character. The dip of these beds is S. 25° E. at 50°, so that it is evident that we are dealing with a syncline, the southern limb of which forms the ridge of Cincoed. Near the northern margin of the map the *Dicranograptus* Shales Mr. Thomas.

Mr. Thomas. are faulted against Llandilo Flags. The structure of the country leads to the inference that the fault is an overthrust, and that the flags have been pushed from the north over the newer strata.

The black shales of the Ty-newydd Quarry have yielded *Climacograptus* sp., *Diplograptus foliaceus*, *Dicranograptus ramosus*, and *Siphonotreta micula*.

On the northern flank of Allt Cincoed, in a large quarry below Quarry Farm, the upper limestone band has been extensively quarried; the limestone is full of organic remains, chiefly of *Orthis testudinaria*, Dalm. The lower limestone has as yet yielded no fossils in the Ty-newydd Quarry, but it has been quarried above Pen-y-goilan, one-third of a mile E.S.E. of Llanegwad, where it is fairly fossiliferous. The fossils consist chiefly of small brachiopods and crinoid ossicles. These above-mentioned limestones may be equivalents of the Bala limestone in Mr. Cantrill's ground, or they may be only a local calcareous development of the *Dicranograptus* Shales, the top of these shales being absent to the east of Carmarthen.

Two isolated patches of these shales form striking hills on the south side of the valley, namely, at Capel Dewi and at Llangunnor. The exposures are bounded on the north by the Towy alluvium and on the south by an east and west fault of considerable magnitude by which the shales are thrown against much older strata.

The shales on the north side of Capel Dewi hill have yielded an abundance of *Diplograpti* and an *Orthoceras*. They are evidently on the same horizon as the beds of Ty-newydd and Cincoed, that is fairly high up in the *Dicranograptus* Shales. At the summit of Capel Dewi hill a limestone is seen which apparently overlies the graptolite shales.

The Llangunnor mass is lithologically similar to that of Capel Dewi, except that the limestone is absent and fossils are extremely rare.

Mr. Cantrill. The *Dicranograptus* Shales are exposed at Mylet Quarry, south-west of Lower St. Clears, and again at Llandilo Abercowin. They are intensely black and contain abundant graptolites, chiefly *Diplograptus foliaceus* and *Dicranograptus*. From the left bank of the Tâf at St. Clears Bridge they yielded to Professor Lapworth,* *Dicranograptus formosus*, *Diplograptus foliaceus*, and *Climacograptus perexcavatus*.

The uppermost beds are sandy and less fossiliferous.

Sholeshook and *Robeston Wathen Limestones*.—The *Dicranograptus* Shales are succeeded by sandy and impure thin-bedded dark limestones well exposed at Llandilo Abercowin, Trefanty and Foxhole, and Bron-haul. Farther west, at Maes-y-lan, they become particularly sandy. They yield *Cybele verrucosa*, and various corals, including *Heliolites* and *Halysites catenularia*. The two limestones of the typical district appear to be represented hereabouts by a single band.

* *Ann. & Mag. Nat. Hist.*, ser. 5, vol. iv. pp. 339–340 (1879).

The *Redhill Beds* are a thick series of blue-grey mudstones containing *Favosites fibrosus* and other corals, as well as crinoids; they are exposed at Maes-y-grove, south-west of St. Clears, and are succeeded at Morfa-bâch quarry by mudstones more evenly-bedded, with occasional thin bands of decalcified earthy limestones, which may correspond to the lowest horizons of the succeeding Slade Beds of Messrs. Marr and Roberts. Mr. Cantrill.

South of St. Clears, where there are many sections in these rocks, the structure of the ground indicates the existence of several anticlines and synclines having a general east and west direction, cut somewhat obliquely by faults, some of which are probably thrusts.

Igneous Rocks.—An interesting group of igneous rocks which appears to include both contemporaneous and intrusive materials forms some picturesque ground at Coomb, near Llangynog. The examination of this tract is not yet complete.

OLD RED SANDSTONE.

The lower part of the Old Red Sandstone consists of about 450 feet of green sandstones and marls * passing up through an alternating series of red and green beds into the normal red marls, sandstones, and conglomeratic cornstones which constitute the mass of the lower or Red Marl sub-division. Mr. Thomas.

A well-defined basal conglomerate developes westwards at the base of these green beds. Where first seen in Nant-y-caws dingle it is about two feet thick and includes pebbles of quartz, quartzite, jasper, ash, sandstones, etc. It thickens westwards, and the size of the pebbles increases, while certainly one more bed of conglomerate makes its appearance at a higher position in the green series. The conglomerate is well seen in Pen-y-coed dingle and below the bridge at Cwm-ffrwd, on the east of the Towy, and at Green Castle on the west.

What is the base, or nearly the base, of the Old Red Sandstone occurs at Glôg-ddu. The rock is a conglomerate with rounded pebbles, some of which resemble ashes. It is massive and the bedding so obscure that the dip could not be determined. South of it there is a considerable space in which no rock is visible; but further on in the same direction red marls and sandstones, the latter containing small bands of cornstone, are exposed to view on both sides of the Towy. Mr. Wilkinson.

The same buff and green calcareous marls with micaceous sandstones have been traced south-westwards past Llangynog and Llandilo Abercowin as far as the neighbourhood of Llandowror. They contain occasional bands of conglomerate derived from various older rocks. Here also they pass up by alternation into red marls with occasional beds of sandstone. Mr. Cantrill.

At Pen-y-bont, nearly a mile north of Towy Castle, there is a change of dip which indicates an anticline running in a N.E. and Mr. Wilkinson.

* Reference to these basal green beds was made in the *Summary of Progress* for 1902, p. 41.

S.W. direction. South of this the dip is fairly steady towards the S.S.E. for some distance, so that there must be a considerable thickness of red sandstones and marls. These red beds are succeeded upwards by reddish and green micaceous sandstones, with partings of red mudstone and marl, the latter containing a few cornstones.

Mr. Strahan. One of the most massive cornstones yet met with forms a low cliff south of Llanstephan Castle, while what is not improbably the same band has been quarried in several places on the hill-side north-east of Ferryside. In the cliff the structure of the cornstone and of the marls associated with it is admirably exhibited. The following descending section commences at a point east of the castle :—

Cliff-section east and south of Llanstephan Castle.	Ft.
Red and green marls, base not seen	
Green sandstone and rocky marls—pteraspidian fish	30
Red and green marls, 10 feet of red marl at base	28
Green laminated sandstone, plant-remains in the lower part	5
Green sandstones and marls with thin cornstones	20
Red marl, with large calcareous concretions in the lower part	26
Green marl	
A small overthrust.	
Green sandstone	4
Sandstone, conspicuously streaked red and green	6
Red marl with calcareous concretions in lower part	21
A small crush.	
Red marl with bands of concretions or of concretionary cornstone; streaked with green in the lower part	30
A small overthrust.	
Red concretionary marls	14
Green sandstone and cornstone	12
At this point there are steps down the cliff.	
Massive rock, full of white calcareous concretions in a green, or occasionally red, matrix. The longer axes of the concretions are vertical to the bedding	7
The same, but the concretions so large and close as to constitute an almost solid limestone. The structure due to the vertical arrangement of the concretions is conspicuous	10
Red parting of similar rock	1
Massive greenish limestone as above	9
Limestone, solid in places, but occasionally showing a little green matrix between vertically placed concretions. Seen to	20

At this point the cliff runs along the strike and is formed by the same strata for about 400 yards. The beds then turn over and dip southwards, so that the section given above is repeated in reverse order. It is difficult, however, to recognise individual bands.

The most noticeable feature in this section, apart from the evidences of subsequent disturbance, is the occurrence of the calcareous concretions. They vary in size from a pea to 6 or 8 inches in length. In some of the smaller bands of cornstone they appear to have

been rolled and are associated with rolled fragments of other rocks, but in the massive limestones they evidently stand in the position in which they were formed. It is especially to be noted that some of them were formed as rudely shaped cylindrical masses, with an upward growth, which kept pace with the deposition of marl around them. In this respect, and in the fact that they were dotted over the bottom in varying closeness, they recall the arrangement of certain cylindrical flints in the Chalk. One of these concretions has been sliced and is described by Dr. Flett as follows :— Mr. Strahan

E. 4035. Dark-grey crystalline limestone. Dissolves readily and completely in cold weak acid. Contains a few small quartz-grains, and darker fine concretionary patches.

Above the Red Marls come the green sandstones of the Senni Beds, which are about 300 feet thick, and have been quarried for flags near Crwbin. The succeeding Brownstones are scarcely distinguishable from the Red Marls, but towards their summit they contain bands of coarse sandstone which is pebbly and often olive-green in colour. These are overlain by the Carboniferous Series. Mr. Cantrill

The Old Red Sandstone between Ferryside and Kidwelly may be referred with certainty to the lower Red Marls sub-division and to the Senni Beds. North-east of Kidwelly there appears to be a thin representative of the Brownstones which, however, disappear to the west. The Red Marls, as is clearly shown in the railway-cutting south of Ferryside, include a considerable amount of green, micaceous flags indistinguishable lithologically from the Senni Beds. These themselves, moreover, are linked with the Red Marls by the fact of their containing subordinate bands of that material, though they consist chiefly of green, micaceous flags. Their thickness is probably about 600 feet near Kidwelly, and they form high ground, as in the neighbourhood of Allt-cyn-Adda. Thence the crop passes to the coast near Tan-y-lan, but an outlier occurs to the north of that place, which at Pen-y-gau has yielded from a thin band of grey, flaggy sandstone a number of shields of *Pteraspis* as hereafter noted. Mr. Dixon.

In the higher part of the Senni Beds there is a band, or possibly in places several bands, of white quartzite, which, perhaps, never exceed 10 feet in thickness, but which form several small crags north of Kidwelly. Some of these have yielded several plant-remains resembling Stigmaria and one like a Calamite.

A similar band has been recognised at Llech-dwnny, 1½ miles south-east of Llandyfaelog. There in spite of some obscurity we may be sure that it lies not immediately below the Carboniferous Limestone. West of the Gwendraeth-fach it has been traced almost continuously from a point north of Rogerlay, past the outlying crags mentioned above, to Pen-allt, where it is close to the Carboniferous Limestone, but beyond Pen-allt no trace of it could be found. Therefore it and presumably the upper part of the Senni Beds either thin out or are overstepped westwards by the Carboniferous Limestone. The irregularity of deposition which characterised

Mr. Dixon. the Old Red Sandstone makes it quite possible that the beds thin out, but there are certain facts which point to an unconformable overlap by the Carboniferous rocks. For example, as may be seen in the case of the Senni Beds, the whole of which are exposed at Glan-Rhydw near Llandyfaelog, there is, here as elsewhere, perfect conformity throughout the Old Red Sandstone, yet the lower part of the Senni Beds contains a fauna characteristic of Lower Old Red Sandstone. It is worth noting also that the basal beds of the Limestone contain sandstones with some small, scattered pebbles. The diminution of the Senni Beds commences at the point where the overlying Brownstones disappear. These overlying strata, moreover, show a similar attenuation in the same direction, all of which facts are explicable on the theory of an uncomformable overlap by the Carboniferous rocks.

Near Llandyfaelog the Brownstones include greenish sandstones and fine conglomerates at any horizon, whereas to the east the highest beds chiefly have this character.

Fossils.—Hitherto no fossils have been recorded from this district, but in addition to the plant-remains referred to above, a number of poorly preserved ventral shields of fish have now been obtained from a greenish sandstone low down in the Senni Beds at Pen-y-gau. They have been identified as *Pteraspis*.*

In material thrown out from the railway-cutting between St. Ishmael's Church and Ferryside, there have been found fragments of dorsal shields of *Pteraspis*,* probably *P. Crouchii*. It will be remembered also that remains of a pteraspidian fish have been found near Llanstephan (p. 36). The occurrence of these forms leaves no doubt that the strata are of Lower Old Red Sandstone age.

Mr. Jones. In the neighbourhood of Red Roses, south of Whitland, two subdivisions are possible in the Old Red Sandstone, namely, a great mass of red and brown marls with sandstones, and below them some green marls.

The green marls are well-developed on the south side of a disturbance which runs east of Red Roses and along the high road to St. Clears. They dip south at fairly high angles, and are estimated to be about 500 feet thick. They frequently contain calcareous nodules, which on weathering out leave cavities and give the rock a curious honeycombed appearance. The best section is in the brook east of Cwm Farm.

Although red and brown marls form the main bulk of the overlying rocks, yet green and purple beds occur sporadically. Sandy marls and sandstones are frequently present in thin bands; the sandstones are more abundant in the upper beds than in the lower, and the prevailing colour is brown rather than red. Coarse greenish and grey grits and conglomerates are found all through at intervals.

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* Ventral shields of this genus were formerly called *Scaphaspis*, but their true nature has been demonstrated by A. von Alth. (*See* A. Smith Woodward, Catal. Foss. Fishes, B.M. pt. ii, p. 161.)

One band of the latter contains abundant flakes of a green marl on which it rests, together with large pebbles of quartz. In the neighbourhood of Gelli-halog, immediately below the Carboniferous series, there are green and buff marls with flaggy micaceous sandstones; they have not been observed at this horizon in the ground farther to the east. Neither the Senni Beds nor the Brownstones have been recognised. Mr. Jones.

CARBONIFEROUS.

Carboniferous Limestone Series.

The Lower Limestone Shales at Ffynnon Cadachog east of Llangyndeyrn are about 40 feet thick and consist of dark greenish-grey shales with thin bands of crinoidal and shelly oolite, some of which is red. Mr. Cantrill.

The Main Limestone is about 600 feet thick, and forms a bold escarpment along the south side of the Gwendraeth-fâch valley east of Llangyndeyrn. The lithological subdivisions which were established in ground lying many miles to the east here show signs of breaking down. Although the lower half consists generally of limestone or fine-grained oolite of a dark tint, yet in many of the exposures the rock is of a light-grey colour. This is overlain by a band 20 to 30 feet thick of light-grey limestone in which the oolitic structure is more strongly marked—a character which has distinguished the limestone at this horizon for many miles along its northern outcrop. This light oolite is followed by a considerable thickness of dark oolite and dark limestone with chert, but here again the rock locally becomes light-coloured. Above these succeed black shales (Rottenstone Beds), and these are overlain by the "plastic-clay" beds, neither of which is worked, however. Above these follows immediately the basement grit of the Millstone Grit.

At Fan Quarries the limestone forms a fine escarpment, broken only by a N.N.W. fault which runs up a hollow to the west. The limestone is thrown southwards by the fault and reappears at Greenhall, whence it runs as a fine ridge south-westwards. In the Fan quarries several masses of spar and fault-rock have been left standing like so many parallel dykes. They range about N. 10° W. Mr. Wilkinson.

The uppermost limestones of the quarries are light-coloured and oolitic; the lower beds are also oolitic but darker in tint. A specimen taken from near the top of the formation near Greenhall Farm is found by Dr. Flett to be an oolitic limestone with foraminifera, fragments of shells, corals, crinoids, etc. Enormous quantities of limestone have been quarried in past times, but the industry has almost died out in this neighbourhood. The outlier of limestone near Llandyfaelog, alluded to in the *Summary of Progress* for 1902, p. 46, is a somewhat massive light-grey oolite.

In several cases huge masses of Millstone Grit have subsided into swallow-holes in the limestone. Boulder-clay lies upon some of the subsided masses, showing that they sank in pre-Glacial times.

Mr. Dixon. The subdivisions of the limestone which, as previously mentioned p. 39), show signs of breaking down east of Llangyndeyrn become quite indefinite nearer Kidwelly, where also the sequence is interrupted by strike-faults. The Lower Limestone Shales consist of shales and earthy, oolitic limestones, etc. In the banks of the Gwendraeth-fach below Old Forge they include sandy limestones and sandstones, in part pebbly, which have in places been subsequently silicified and closely resemble quartzites. Unfortunately the junction with the Old Red Sandstone is not well exposed, but the beds above are parallel to those below.

The lower part of the Main Limestone is dark and generally unfossiliferous, but sometimes oolitic. Higher in the sequence the rock is less dark and the oolitic grains are larger. Thus the limestone becomes a typical light-grey oolite with occasional thin bands only of darker rock, each generally underlain by a thin shale. Near the base of the light oolite there is a constant bed of sandstone sometimes coarse-grained and about seven feet thick, deeply honey-combed when weathered.* Fossils are frequently abundant in these higher beds. In the uppermost fifty feet of the limestone the oolitic character gradually disappears and the rock consists largely of corals, crinoids and bryozoa in an amorphous paste. No trace of chert was seen anywhere.

Evidence of the existence of the soft shales and earthy limestones which constitute the Upper Limestone Shales has been obtained on Mynydd-y-gareg. They are rarely exposed, but were traversed by the shaft of a small lead-mine east of the old lime works. The tip contains many fragments of light-grey chert, in which search has been made for radiolaria, at present without success. Chert-rubble is exposed in a small pit dug for the decomposed shale near the same place in strata occupying the same horizon.

Mr. Strahan. Further examination of the cliff under the Black Rock Quarry, near Llanstephan, has disclosed the junction of the Carboniferous Limestone and Old Red Sandstone in one of the shoots by which the limestone was sent down to the beach. The complete section follows :—

Black Rocks.

		Ft.
Lower Limestone Shales.	In the quarry, thin-bedded limestone and shale formerly worked for building and agricultural purposes	40
	Beds not seen, but chiefly shale	25
	In the shoot, thin bands of dark earthy limestone in shale	4
	Dark limestone with smooth fracture	2
	Shales with thin limestone; greenish or buff in the lower part	6
	Soft friable grit with quartz-grains and small included lumps; greenish	½

* The occurrence of a similar band in the North Crop further east was noted in the *Summary of Progress* for 1901, p. 40, and its temporary disappearance in the Summary for 1902, p. 42. There also the sandstone lies below a light-coloured oolite.

		Ft.	
Old Red Sandstone	Hard green sandstone, highly micaceous	6	Mr. Strahan.
	Rocky green marl passing down into	15	
	Red marl	20	
	Green sandstone, seen to	8	

Though no discordance between the two formations can be detected, there is little to suggest a passage. On the contrary the junction is sharp, and definitely separates rocks of two characteristic types. There is, moreover, some appearance of erosion. The section compares well with that exposed at East Lanteague Farm, while on the other hand it presents remarkable differences to the exposures of the same junction in Gower.

In the area south of Whitland the Lower Limestone Shales are well-exposed near Crunwear. In the corner of the pond at East Lanteague Farm they contain fossils (bryozoa and brachiopods). In the road-side just outside, still lower beds are seen as follows, in descending order :— Mr. Jones.

	Ft.	In.
Olive-green shales, weathering yellow		
Rottenstone, 8 inches to		10
Greenish calcareous shales	1	6
Pebbly bed with quartz pebbles		2
Ferruginous grit		6

The ferruginous grit rests with a sharply defined base on some green marls of the Old Red Sandstone.

Another exposure is yielded by a stream on the west side of the lane about 400 yards north of Trenewydd Farm. The occurrence of the shales here is explained by a disturbance which throws the base of the Carboniferous Series about 400 yards to the north. They are olive-green and yellowish in tint and contain abundance of fossils, among which *Syringothyris cuspidata*, *Parallelodon?* and *Pterinopecten* have been identified.

Another good section of what appear to be the basal beds is visible on the east side of the lane leading to Gellihalog Farm and about 80 yards north of the house. It shows in descending order :—

	Ft.	In.
Greenish and buff marls and sandstone in thin irregular beds	2 ft. 6 in. to 3	0
Coarse greenish open-grained sandstone, becoming finer towards the top	3 ft. 6 in. to 4	0
Coarse-grained greenish grit and conglomerate with large pebbles near the bottom, finer-grained towards the top, becoming in places a buff marl	2 ft. 6 in. to 3	6
Very rotten ferruginous grit and conglomerate with pebbles up to ¾ inch in diameter. A few lenticular patches of buff marl, one being 10 inches in diameter; about	2	0
Old Red Sandstone. Green and buff marls.		

The strata all dip south and in that direction, beyond a gap of about eight yards obscured by detritus, there are ferruginous shales with an extraordinary abundance of Carboniferous fossils. Here again what we take to be the basal bed of the Carboniferous shows

. Jones. sharp demarcation from the green or buff marls on which it rests. It is difficult to prove a discordance of dip although it is suggested by the section.

Buff shales and rottenstone with fossils occur about 1,000 yards N.N.E. of Blaencilgoed in a somewhat anomalous position which indicates a further throw of the base to the north.

Two sections in the upper part of the shales remain to be noticed. The first is furnished by an old quarry on the west side of the stream about a quarter of a mile S.S.W. of Castle Ely Bridge, and shows in descending order :—

	Ft.	In.
Grey and reddish-brown coarsely crystalline limestone, seen to	1	6
Light-grey fine-grained crystalline limestone interlaminated with shales	3	0
Soft dark laminated shales	1	6
Dark-blue earthy limestone		9
Shales, as above	1	0
Dark-blue earthy limestone		6
Soft dark shales, ironstained on weathered surfaces, and thin bands of dark-blue earthy limestone weathering brown	1	0
Light-grey coarsely crystalline limestone with thin shale partings, seen to	5	0

In the second exposure, which occurs in a small cave at the north-east end of the Croft Quarry at Blaencilgoed, about 10 feet of soft ironstained shales with thin bands and patches of coarse reddish-grey limestone are seen under black compact limestone. The transition from the grey to the black limestone is somewhat abrupt.

Considerable difficulty has been experienced in mapping the Main Limestone in the part of the outcrop ranging from Pendine to Ludchurch, owing to the way in which it is obscured by Drift and material of a somewhat peculiar character which will be noticed under the head of Drift. The rock is seldom exposed except in quarries, and its presence is indicated chiefly by the uneven ground and numerous swallow-holes. The quarries are all in the lower portion, the bulk of which is a dark-blue rock of fine-grained character. Thin bands are crowded with fossils and oolitic structure frequently occurs. A light-coloured oolitic rock with ill-defined bedding is occasionally exposed. It is seen at the top of both the Castle Ely and the Trenewydd Quarries and in some of the small quarries at the foot of Marros Mountain. The uppermost beds of the limestone series are nowhere visible.

Millstone Grit.

. Cantrill. The basal grit is well displayed in numerous crags on Mynydd Llangyndeyrn ; the middle or shale subdivision contains numerous but impersistent bands of olive-coloured flaggy quartzitic sandstone, some of which have been quarried north of Pontyberem and Pont Yates. In the absence of any well-marked and persistent representative of the Farewell Rock at the summit of the shales the divisional line between the Millstone Grit and the Coal-measures is indefinite and arbitrary.

In the neighbourhood of Meinciau the basal rocks consist of white quartz-sandstones often much stained, succeeded by massive quartzites. These are followed by dark shales with a band of brown argillaceous sandstone. The basal sandstones are often weathered into a friable sandstone or sand, and two specimens were collected for the purpose of ascertaining the nature of the change. The specimens, of which the first is a weathered rock and the second the same band unweathered, are described by Dr. Flett as follows:— Mr. Wilkinson.

E. 3976. A fine grey or slightly lilac sandstone, discoloured in places with ferruginous stains. It is composed almost entirely of small grains of quartz, with very little felspar or clear mica, some zircon, garnet, and tourmaline. The quartz-grains are subangular and average about ·05 millimetre in diameter. Dark brown stains of limonite have percolated into the rock in some places.

E. 3977. Similar rock, but more compact and harder. The previous specimen is friable and distinctly porous. The difference is due to the siliceous cementing material being less abundant between the grains. This may be a result of weathering.

North-east of Kidwelly the three divisions of the Millstone Grit may be traced with some precision. The basal grit where undisturbed consists of white, tough quartzite with subordinate bands of buff or black shale rarely as much as five feet thick and sometimes mixed with powdery coal for a thickness of a foot. But near faults, or in swallow-holes in the Carboniferous Limestone, where the rock is broken and percolating water has removed its siliceous cement, it becomes friable and may even pass into the condition of loose sand. Some of the swallow-holes which it fills are huge and very old, as may be judged by their distance from the Millstone Grit scarp and from the fact that they are overlain by Boulder-clay. The numerous quarries on Mynydd-y-gareg give many opportunities of making these observations. Mr. Dixon.

Of the shales which lie above the basal grit only the higher beds are open to examination, the rest being obscured by drift. The nature of the junction therefore is unknown, but the shales pass upwards into current-bedded shaly sandstone, the base of the Farewell Rock. In the dingle at Cae-tir and about 50 yards below the base of this sandstone there is a coal four inches thick with a typical underclay. A seam, six inches thick, which may be on the same horizon, has been worked by levels from the dingle above Morfabach, and possibly on the ridge south of Capel Teilo also; but it has not been found elsewhere. The ridge just mentioned is caused by a sandstone in the shales just below the horizon of the coal.

To these shales probably belong the shales and fine sandstones in the river-bluff on which Kidwelly Castle stands.

The passage-bed at the top of the shales is overlain by fine-grained, olive-green sandstone, 10 to 20 feet thick, which passes up by intercalation into the lowest beds of the Coal-measures. It can be seen at intervals beneath the Drift on the north-west side of the Gwendraeth-fawr and is well exposed at Pont Newydd. On the other side of the river a sandstone exactly resembling it is exposed at Tal-carn, north of the Morlais River, and this also is underlain by

a current-bedded sandstone resting on shale which for at least 55 yards contains no coal. The identification of this sandstone with the Farewell Rock is supported by the character of the Coal-measures immediately above and is of importance in unravelling the structure of the Trimsaran district.

r. Jones. With the exception of some doubtful exposures on the north side of Marros Mountain the lower part of the basal grit is nowhere exposed in the crop extending from near Greenbridge to Ludchurch.

The middle or shale subdivision consists in the lower part of dark, thin-bedded shales well exposed near Garnass Farm, and in the gorge and slopes north of Marros Mill. A band of grit of the same character as the basal grit gives rise to a small cascade in the gorge.

Above the shales and forming well-marked crags is a hard, quartzitic, flaggy sandstone, current-bedded in places near the base, and about 40 feet thick.

It is succeeded by a great thickness of shales with some sandstone. The greater part of these is laid open to view in the coast-section which commences near Underhill and continues with but slight interruption to New Inn, Amroth. The following is a generalised account, in descending order, of the portion that may be assigned to the shale sub-division :—

	Ft.	In.
Flaggy sandstone and sandy shale ; the upper portion consists mainly of shales with sandstone beds, about	130	0
Black shales with a few bands of mine ; they become more sandy towards the top, and pass gradually into the sandstone above, about	100	0
Current-bedded sandstone with flaggy, sandy shales, and some black shales, about	30	0
Shales, very black near the base, grey and more sandy towards the top ; seen to about	100	0

The shales and sandstones seen in this section form the high ground about Marros Beacon, and may be traced thence in a general westerly direction by the good features which they form.

The continuation of the cliff just described from Telpen Point westwards shows what may be taken as the Farewell Rock :—

	Ft.	In.
Sandstone, and sandy shale 3 ft. to	6	0
Hard quartzitic sandstone in regular beds of 1 to 2 feet thick, about	12	0
Hard greyish quartzitie sandstone or grit, with well-marked current-bedding, 45 feet to	50	0

This basal member is fairly sharply separated from the somewhat shaly beds below. The upper member is only arbitrarily separated from the Coal-measures, the transition being quite gradual.

Coal Measures.

. Strahan. The part of the Coal-field surveyed during the year 1903 lies between Tumble and Kidwelly. Its examination is not yet complete, and some important questions relating to the correlation

of seams, the effect of disturbances, and the extent of the Coal-field beneath the sea still await solution. The results so far arrived at will be found in Appendix III, p. 162. Mr. Strahan

FAULTS AND DISTURBANCES.

The observations on which the following generalisations with respect to the disturbances are founded, will be found partly in the foregoing pages and partly in the Appendix on the Coal-measures of the Gwendraeth Valley.

One line of disturbance ranging in an east and west direction and five ranging west-south-west have been under investigation during the past year. The first named is a broken anticline running from the Lliedi Valley near Gelli-lysged, by Cefn-y-bryn and along the Morlais, near Trimsaran. It is accompanied by much overthrusting, and in a part of its course appears to throw the measures down northwards. The disturbance runs parallel to the Llanelly syncline, and forms the line along which the north rise from that syncline terminates. The Llanelly syncline connects itself with the series of folds which traverse Gower, and which are there proved to be of pre-Triassic age.

The five lines of W.S.W. disturbance include :—

1. The Kidwelly Disturbance which runs west of the Castle and Mynydd-y-Gareg. The net result of the various fractures of which it consists is a downthrow south-east.
2. The Llanstephan Disturbance runs from the coast near Black Rocks up the Iscoed dingle, past Llandyfaelog to Bryn-yr-odin.* It is everywhere a powerful downthrow to the north-west, but not of such great size as the outlier of limestone at Llandyfaelog seemed at first sight to indicate.
3. A belt of disturbances runs near and along the Towy Valley east of Carmarthen. The southernmost is a great downthrow north-west, and introduces an inlier of Ordovician rocks in the Old Red Sandstone.
4. A powerful disturbance, accompanied by inversion, passes near Llangynog ; this is likely to prove to be continuous with the Towy Valley disturbances, when the intervening ground is examined.
5. A disturbance which runs along the St. Clears road past Red Roses and duplicates the outcrop of the limestone further west. This is a downthrow north-west.

The parallelism and general similarity of these structures to one another and to the Cribarth and Neath Disturbances justifies the inference that they all belong to one system. The relative age of that system to the pre-Triassic disturbances has been discussed elsewhere.†

* Proofs of its position were given in the *Summary of Progress* for 1902, pp. 45, 46.

† Summary of Progress for 1902, p. 48.

Strahan. 1. The description of the Kidwelly Disturbance will be found in the Appendix, p. 171.

2. The Llanstephan Disturbance was described in the *Summary of Progress* for 1902. It was then mentioned that a gentle anticline runs parallel to the Llanstephan disturbance with some small overthrusting. Further observation has led to the following notes on the connection between the two structures. The northern limb of the anticline is exhibited in the cliff between Llanstephan and St. Anthony's Well. The strata dip at 35° to 50° northwards, the axis of the fold running a few yards south of the cliff. Three fractures may be detected in the part of the cliff which lies to the east of the Castle, and faces east. One is a nearly vertical crush, but the others are well defined overthrusts dipping northwards at a slightly lower angle than the beds.

In the part of the cliff which faces south, and at a point about 70 yards west of the steps south-west of the Castle a normal fault cuts through the beds and the structures of the east and west system throwing them all down one foot to the west. A little further on there is a considerable overthrust which dips north at a steeper angle than the beds, and the effect of which in cutting out some green sandstone and marl can be traced step by step on the foreshore.

At St. Anthony's Well the cliff again turns southwards, and cuts through the anticline at right angles. For the first 150 yards it shows the northern limb. Here, again, in this limb we find a series of overthrusts dipping north. All rise at a slightly higher angle than the bedding, and probably in none does the movement exceed three or four feet.

The crest of the anticline takes the form of a gentle arch. In the crest and within a space of a few yards there are five or more small overthrusts. Those on the north side of the crest dip north, those on the south side south. The structure therefore resembles what would be produced by the crushing of an arch and the thrusting upwards of the sides over the crown. South of the crest the strata dip gently southwards, and we find several overthrusts all dipping in the same direction, but whereas those of the northern limb are all at high angles, those of the southern limb are generally at low angles or even horizontal. One of them is conspicuously shown by the fact of its displacing some purple marl and green sandstone as much as 25 yards horizontally. But a more remarkable structure is shown at the turn of the cliff westwards on approaching Wharley Point. Here the strata curve rapidly from a gentle to a high southerly dip. An undulating, but on the whole horizontal, thrust cuts through the curve and shifts strata with a high dip on to the top of strata with a low dip, the displacement being about 11 yards horizontally. The fracture can be traced for a considerable distance in the lower part of the cliff, and then descends southwards below the beach. At the point of disappearance a subsidiary fracture, with an overthrust of about 4 yards, rises from it at a steep angle.

The following points are established by this section. On the north side of the anticline, the dip is steep and the overthrusts are nearly vertical; all are thrusts from the north. On the south side of the anticline the dip is low, and the overthrusts are nearly horizontal; all are thrusts from the south. Anticline and overthrusts are parallel, and obviously contemporaneous. The structure illustrates how a combination of folding and overthrusting may afford relief from lateral pressure, and proves that overthrusts of opposite hade may be produced simultaneously by the same movement. Mr. Strahs

Further examination of the ground about Llandyfaelog shows that the Carboniferous Limestone there * is not separated from the beds to the north by a large fault, as these are the higher divisions of the Old Red Sandstone, the Brownstones and Senni Beds, in normal order of succession. The Senni Beds which are the better exposed appear north of the disturbance near Pont-Antwn and running at first due west, then south-west and finally south end against the disturbance immediately north of Llandyfaelog, thus completing a crop parallel to the northern boundary of the limestone outlier. Apparently therefore the disturbance is more of the nature of a single break than a trough-fault. Mr. Dixon.

The examination of the ground to the south of the disturbance is not yet finished, but it is certain that the throw of the fault is much less than would be inferred from the distance of the outlier from the main limestone-scarp. For the Senni Beds extend from that scarp as far as the disturbance at Pont-Antwn.

3. The strike of the rocks of the area east of Carmarthen has been determined by a series of folds with axes running a little N. of E. and S. of W. Mr. Thoma

The lines of fracture are of two types (*a*) parallel to the main direction of the folds; and (*b*) in the direction of dip, or, in other words, at right angles to the other set. The first mentioned type seems the most important and affects the greatest area. But so far it is only in fissures of the second type that metalliferous deposits are met with.

The east and west disturbances are many in number; a most important line of fracture may be traced all along the Towy Valley as far west as Carmarthen. The river then leaves the fault valley and runs southward. Both sides of the valley are bounded by faults of which the most southerly seems of greatest throw.

Several lines of disturbance traverse the Arenig and Tremadoc rocks, passing from them into the Old Red Sandstone. They have a downthrow north with the result that the base of the red rocks is thrown in a northerly direction, while at the same time faulted inliers of older rocks appear with Old Red Sandstone on both sides of them.

A good example of this is seen in a disturbance which enters the Old Red Sandstone near Gelli-uchaf on the Llanddarog Road, passing by Ty-hen, below Brigwellt-y-coed, to the north of Bwlch Garw

* Summary of Progress for 1902, p. 46.

Mr. Thomas. and on in a W.S.W. direction, under a large drift-covered area. An inlier of grits and mudstones of Tremadoc age is seen at Llwyn Melyn and Bwlch Garw. At the last-named these rocks yielded *Peltura punctata*, *Ogygia marginata*, and some small lamellibranchs. The inlier is more than a mile in length and one-third mile in greatest width.

This line of disturbance seems to be the same as that which forms the northern limit of the Silurian from the neighbourhood of Llandilo.

Of the north and south fractures the most important are those of Allt Cystanog; they are fairly straight in their course and dip to the east at an angle of 60° to 80°. The lateral displacement of the beds on either side seems to be about 100 yards.

Nearly all these north and south faults have been mined or tried for galena.

Cleavage.—The cleavage of this district is remarkable for its sudden appearance. The rocks on the south side of the Towy are only locally cleaved in the neighbourhood of some large disturbance. On the north side of the river the cleavage is of the regional type, its direction following the main folding of the country, and the planes having a dip in a northerly direction of 40° to 70°.

Occasionally there has been much movement along the planes, and a more or less complete obliteration of the bedding, except for infrequent streaks of more sandy material in the shales. Under these circumstances the fossils are badly preserved. Generally, however, the cleaved rocks will yield identifiable fossils.

Mr. Cantrill. 4. The connection of the Towy belt of disturbances with what appears to be inversion on a large scale near Llangynog is still under investigation.

Mr. Jones. 5. East of Red Roses there is evidence of a considerable disturbance cutting through the Old Red Sandstone in a direction W. 20° S. On the south side of the valley along which the main road runs a great mass of green marls dips south at fairly high angles, while on the north side are red marls dipping N.N.W. It has been already shown (p. 35) that green marls form the basal portion of the Old Red Sandstone. If, as is probable, the green marls here seen represent this basal series, the disturbance must be a downthrow to the north. The valley follows the disturbance closely for some miles, but comes to an end near Red Roses. West of that place the line is taken up by another valley, which follows it for a mile and a half, and which also shows opposing dips in its two sides, those on the south side reaching so high an angle as 60° to 70°. The two valleys fall exactly into one line and present the same narrow, steep-sided character. They offer a marked contrast in direction to the rest of the valleys in the district, which trend north and south.

This valley also terminates, but still in the same line, and less than a mile west of Crunwear Rectory, Lower Limestone Shales project far out into the outcrop of the Old Red Sandstone, in a

manner which implies a considerable downthrow to the north. This evidence leaves little room for doubt that the disturbance runs continuously from the main road east of Red Roses to the limestone west of that place. How much farther in either direction it may be traceable remains to be seen. Some distance to the west the limestone is further affected, but the structure there is still under investigation.

In many places in the neighbourhood of the disturbance a peculiar fissile structure is set up in the marls; in small exposures this may easily be mistaken for bedding, especially as mica-flakes, by means of which bedding-planes can generally be recognised, are by no means abundant.

GLACIAL.

Mr. Strahan.

In the Summary of Progress for 1902 (p. 49), allusion was made to an ice-flow which travelled westwards down the Towy Valley with a tendency to escape southwards wherever the form of the ground permitted. The region surveyed during 1903 lies mainly in the track of this ice-flow, and has furnished striking evidence that the glaciation was not the work of valley-glaciers, but of an ice-sheet which ignored many, if not all, of the physical features.

The Towy Valley, which as far as Carmarthen runs nearly west, turns southwards at that town. Above the turn it runs more nearly west than the glaciation and was crossed by it at an oblique angle from north to south, as is shown by Mr. Thomas's observations on the composition of the drift; below the turn it was crossed obliquely from east to west, as is shown by Mr. Wilkinson's notes on the neighbourhoods of Llanstephan and Laugharne. The ice therefore pursued its general W.S.W. course across the windings of the valley.

The Gwendraeth-fâch (above Llandyfaelog) and the Gwendraeth-fawr valleys furnish still more complete evidence. They run for some distance parallel, in a direction about W. 30° S., and both follow the strike of the rocks, the Gwendraeth-fâch keeping to the Old Red Sandstone on the one side of the Millstone Grit escarpment, while the Gwendraeth-fawr occupies a strike-valley in the Lower Coal Series on the other side of that feature. The scarp in places reaches a height of 800 feet.

The drift of the Gwendraeth-fâch is found by Mr. Cantrill to be made up chiefly of Old Red Sandstone, but that of the Gwendraeth-fawr to be chiefly of Coal-measure origin, facts which, taken alone, would have led to the conclusion that the glaciation followed the valleys. But the further observation that the drift on the divide at Meinciau is composed almost exclusively of material derived from the Gwendraeth-fâch, prepares us for what is most conclusively proved by striæ. These have been preserved in abundance on the top of the scarp, and all cross the feature obliquely from the Gwendraeth-fâch to the Gwendraeth-fawr. The ice-sheet did not pre-

cisely follow these valleys, deep as they are, but kept its course at an extremely oblique angle across them. Further observations on the same subject will be found in the following notes.

Mr. Thomas. The Boulder-clay of the neighbourhood of Carmarthen maintains the same character as that of the higher part of the Towy Valley. It includes both locally- and northerly-derived fragments. Extensive deposits of flat and moundy gravels occur under and to the south and west of Carmarthen, especially on the flanks of the broad valley leading from Carmarthen to Llanllwch. They rise from the alluvial level which is here twenty feet above the sea, to about 150 feet above sea-level. The material seems to have been derived almost entirely from rocks lying to the north of the valley.

Striæ have been noticed on hard rocks in the neighbourhood of Pant-yr-yn, with a direction W. 40° S.

Mr. Cantrill. The glacial deposits which border the alluvium of the Gwendraeth-fawr valley below Pontyberem consist generally of blue and yellow clay full of stones, sometimes striated, and derived chiefly from the local Millstone Grit and Coal-measures, but in part from older rocks lying to the north and north-east. The same class of Boulder-clay occupies the bottoms of the tributary valleys, and north of Pont Yates extends up to Meinciau (Meincian on map) on the divide between the valleys of the Gwendraeth-fawr and the Gwendraeth-fâch; and here it is much more gravelly and consists almost exclusively of material derived from the Old Red Sandstone of the latter valley.

Below Pontyberem an elongated mound is cut into by the river and shows a section of eight feet of coarse gravel overlying twenty feet of loam.

The Boulder-clay of the Gwendraeth-fâch valley above Llangyndeyrn is made up chiefly of Old Red material, with a few boulders of older rocks; a good section is to be seen in a dingle at Tor-y-coed-isaf, one-third of a mile north-west of Crwbin. At Llangyndeyrn the deposit becomes more gravelly and loamy, and tends to assume a moundy form.

Mr. Wilkinson. A large and typical mound of sand and gravel occurs on the south side of the Gwendraeth-fâch about a third of a mile south of Pont Antwn, and the gravelly character often assumed by the drift is well shewn where this river has undercut a deep bank west of Wenallt. The rock-surfaces on the Millstone Grit escarpment are well-rounded and polished, but the direction of the striæ could not be determined precisely further than that they are in a general south-westerly direction. A little further south on the same range they are more distinct.

Mr. Dixon. In the lower reaches of the Gwendraeth valleys the clayey type of drift prevails, gravel being confined to the lower ground. The largest spread of the latter is in the valley of the Gwendraeth-fâch, east of Rogerlay. About Gwenllian House it has a characteristic hummocky surface whereas to the north and south it is flat and forms a terrace 20 to 30 feet above the recent alluvium.

That the direction of ice-flow was towards the south-west is shown by numerous striæ on the Millstone Grit of Mynydd-y-gareg and on the quartzite crags of the Old Red Sandstone north of Kidwelly. That direction is indicated also by the composition of the Boulder-clay, for at Kidwelly, where it is close to the micaceous flags of the Old Red Sandstone, it nevertheless consists largely of quartzite, probably derived from the Millstone Grit of Mynydd-y-gareg and the valley of the Gwendraeth-fâch.

The presence of much quartzite in the Boulder-clay fringing the coast between Kidwelly and St. Ishmael's Church suggests that the transportation of the drift hereabouts at one time was almost due west, for the only possible sources of the boulders are the Millstone Grit and the highest parts of the Senni Beds, both of which lie to the east.

Mr. Strahan. In the low ground bordering the alluvium of the Gwendraeth-fawr south-east of Kidwelly the Boulder-clay shows by its blue tint and by the character of its boulders that it is made up chiefly of Coal-measure detritus, but even here there are a few fragments of Old Red Sandstone. The absence of the boulders of the Mynydd-y-gareg quartzite, however, which occur in profusion in the little cliffs of Boulder-clay west of Kidwelly Station enables us to fix the direction taken by the drift with some precision. The spot to which the boulders have been carried lies W. 30° to 34° S. of the centre of the Mynydd-y-gareg range. Some striæ situated on low ground on the north side of a mineral railway at Moat, and in a position where the direction of the ice-flow was not influenced by the form of the ground, run W. 29° S.

Mr. Cantrill. Between Llanybre and St. Clears, west of the Towy valley, the drift is mainly distributed along the valleys and over the lower ground, and consists of gravelly Boulder-clay or clayey gravel largely of Ordovician materials. An abundance of red marl fragments in the drift north of Llandilo Abercowin shows that the direction of ice-flow was here more directly westwards than the trend of the Old Red Sandstone base.

Glacial striæ abound on the Millstone Grit of Mynydd Llangyndeyrn and Meinciau, and have a direction averaging S. 40° W., and a good example of roches moutonnées may be seen at Meinciau-mawr; the ice which produced them evidently filled up and flowed down the valley of the Gwendraeth-fawr.

Mr. Jones. In the region between Red Roses and Ludchurch the drift consists of a clayey, sandy, or gravelly matrix with boulders from a variety of sources, a large percentage of them being quite foreign to the area where the drift occurs. Thus over parts of the limestone ground boulders of igneous rocks are not uncommon together with the more abundant Old Red marls, Millstone grit, vein quartz, and probably pre-Old Red grits. A good section in drift of this kind is exposed in a small pit half a mile due south of Westpool.

Nearly all the basal Millstone grit and a great part of the limestone of the region are obscured by material of a peculiar character, the

origin of which is still under investigation. It is a yellowish sandy clay sometimes charged with angular boulders of Millstone grit. According to its nature it has been dug for sand or for clay in different localities. Near Little Ludchurch is a sand-pit 5 feet deep in this material. For the upper two feet it shows dark soil charged with rotten boulders of Millstone Grit, and underneath very fine sand in which occur a few small pieces of vein-quartz, and fragments of Millstone Grit quite rotten externally but with a core more or less unaffected.

Some light may be thrown on the origin of the material by the following descending section taken from a sand-pit in the old lane 700 yards west of Lanteague cross roads.

Dark surface soil with a few blocks of Millstone Grit and some vein-quartz.
Yellowish sand with fragments of Millstone Grit mostly small and not abundant; in it are streaks of a reddish colour containing fragments of Old Red marl. The thickness varies from 2 to 5 feet. It rests with a fairly well-defined boundary on
About 1 foot of reddish-brown sandy clay charged with rounded and subangular fragments of Old Red marls and sandstones. The fragments are of all sizes up to 6 inches in diameter. This rests with but slight intermixture on a creamy-white sandy clay, which contains no rock-fragments. Seen to 2 feet.

The igneous and other rocks occurring as boulders in the drift will be examined in the hope of ascertaining the direction in which they have been transported.

Mr. Strahan. The surface of the Millstone Grit on the ridge south-east of Marros is generally too much weathered to show striæ, but one block is well glaciated. The block has fallen over, but is sufficiently nearly in place to show that the glaciation was in a general westward direction.

POST-GLACIAL.

Mr. Dixon. Peat consisting of leaves and twigs with roots of trees in position of growth occurs on the foreshore south of St. Ishmael's.

Mr. Jones. The remains of a submerged forest are visible at low water for about a mile along Marros sands. Stems and stumps of trees are seen lying about in all directions, but the bulk of the material consists of partially decayed vegetation closely matted together, frequently forming thin layers with intervening layers of a stiff blue clay penetrated by roots and rootlets. The trees appear to have been oaks with possibly some alder.

ECONOMIC GEOLOGY.

Building-stone has been got from various grits and sandstones in the Coal-measures near Pontyberem and Pont Henry. The sandstones below the Brondini Vein which are indistinguishable from Pennant, the few sandstones in the Lower Coal Series, as well as the Millstone Grit and the Carboniferous Limestone have

all been used for the same purpose. The Old Red Sandstone contains some flags, which, with some of the harder marls and cornstones, have served for the sea-wall south of Ferryside. South of Whitland the upper part of the Farewell Rock and a similar sandstone in the Coal-measures have furnished an excellent building-stone, and the sandstones in the middle or shale subdivision of the Millstone Grit were once in great demand for paving; Tenby is said to have been supplied almost entirely from the Talfan Quarries.

Road-metal is got from various parts of the Coal-measures, Millstone Grit and Carboniferous Limestone in the Gwendraeth Valley, and from stones from the Boulder-clay. In the region south of Whitland, Carboniferous Limestone is extensively worked for the purpose, but some of the bye-roads are mended with the harder parts of the Old Red marls. Near Llanybre beach-pebbles are largely used, and at Llangynog some grit bands in the Ordovician rocks are quarried for local use.

Lime was formerly burnt all along the outcrop of the Carboniferous Limestone. In 1903 one kiln only was working at Fan near Meinciau. A dark-blue limestone was formerly burnt near Pendine, but the industry is now dead.

Bricks have been made from marine alluvium at Kidwelly and from alluvial brick-earth at Lower St. Clears. Fire-bricks form a more important industry; they have been made at Ynys-hafren from the fire-clays underlying the Felen and Rhas-fâch Veins and from others.

Silica fire-bricks are burnt near Kidwelly, but the raw material is quarried from the Millstone Grit of Mynydd-y-gareg. The process of manufacture is similar to that of the Dinas fire-bricks.

Iron-ore was formerly worked by "patching" the measures associated with the Rhas-fâch Coal. The industry is said to have been flourishing about 250 years ago, and the ruins of a furnace still stand upon Furnace Farm, Pont Henry. There was another at Ynys-hafren.

Abortive attempts to find coal have been made in many places in black Ordovician shales, and in a Boulder-clay near Morfa-bâch, near St. Clears, which rests on the Redhill Beds. In the latter case the clay had been cemented by chalybeate water; some shafts were sunk into it about forty-five years ago, and only two years ago it was seriously proposed to renew the search.

Four lead-bearing veins cross the hill of Allt Cystanog, namely the old Vale of Towy lode and three others to the east of it. A new shaft recently put down on the south side of the hill in search of one of the eastern lodes, struck a lode at a depth of 52 fathoms. The material raised was galena and a mixture of galena, blende, and copper-pyrites. The vein-stuff contained a considerable quantity of chalybite. The quantity of barytes and galena seemed to decrease, and that of the copper-pyrites to increase as the lode passed from the grits into the shales. The copper-pyrites increased also with the depth.

Galena was worked some thirty years ago along a fault-fissure cross-

ing Merlin's Hill in a N.E. to S.W. direction, in shales of the zone of *Didymograptus Murchisoni*. A shaft was sunk at the north-east end of the hill to a depth of 12 or 13 fathoms and an adit-level driven in along the vein from a point on the cart-road 200 yards north-west of Merlin's Grove Farm.

Copper-pyrites and galena occur in small quantities in the Carboniferous Limestone of Mynydd-y-gareg, where they have been worked.

The water-supply is obtained by impounding springs, deep wells being rarely necessary. Kidwelly is supplied from a spring in the Carboniferous Limestone at Capel Sul; Pont Henry, Pont Yates and Trimsaran from old mines. For Ferryside springs in the Old Red Sandstone have been impounded.

II.—PETROGRAPHICAL WORK.

Dr. J. S. Flett.

The work done in the Petrographical department during the year has included the description of nearly 1,000 English and Scottish rocks for the information of the field officers at work in the various districts or engaged in the preparation of memoirs. Rather more than half of these were English, so that for the first time the English material examined has preponderated over the Scotch. The reason for this is the impending publication of descriptive memoirs on various sheets in Western Cornwall and the consequent need for revision of the whole Cornish Collection. In this work Mr. John Scrivenor, B.A., has given most useful assistance. Large additions have been made by the field officers and by the Petrographer who visited the district in October, and it is hoped that before long there will be in the Museum of Practical Geology a full and representative series of the varied lithological types which characterise this part of England. The microscopic examination of the veinstones which was begun last year, and reported on in an appendix to the Summary of Progress, has been continued with the co-operation of Mr. D. MacAlister.

Much of the work done in this department during the year will be found referred to, more or less concisely, by the district officers in their contributions to this Summary. It may be advisable, however, to mention some of the results which are of special interest from a petrographical point of view.

Mr. Clough has obtained in the granite gneiss complex of Eastern Ross-shire a series of specimens of aegirine-riebeckite-gneiss, a variety of hornblende-gneiss not hitherto reported from the British Isles, and very rare in any part of the world. It is an igneous rock or orthogneiss and corresponds in mineral composition to certain varieties of comendite and paisanite. Analyses of it are being executed and fuller reports will be issued at some future date.

From the same district Mr. Clough has sent a nodule of magnetic iron oxide, which contains cassiterite. This is the first record of this mineral in Scotland. Quartz, felspar, muscovite and biotite

are present also in small quantity. The exact geological relations and mode of occurrence of the tinstone are not yet well understood but will be further investigated during the course of this year.

The source of the withamite of Glencoe, which has hitherto been somewhat of a mystery, as the rocks containing it have not been found *in situ*, has apparently been discovered by Mr. Muff, who has sent in a specimen of a dyke which shows many crystals of that mineral from the Meeting of the Three Waters. There may yet prove to be more than one locality yielding rocks of this type.

Mr. Muff had also sent in some curious rocks of the calc silicate group with tremolite, zoisite and many other minerals from the same district.

Mr. Bailey has collected some interesting variolites, limburgites with soda-microcline phenocrysts, a teschenite and vitrified sandstone full of trin crystals of cordierite all from the Craignish district of Argyllshire. (Sheet 45, Scotland). Dr. Peach has found in the Tayvallich district a group of andesitic rocks, which though decomposed have their igneous structures more perfectly preserved than any which have yet been collected from the Southern Highland or Dalradian series.

At the request of the Meteorological Council, and by permission of the Director, Dr. Flett examined and reported on a large number of specimens of dust collected from the dustfall of February 22, 1903, in various parts of the south and west of England (See *Journal Royal Meteorological Society*, January, 1904).

A great part of the material examined has consisted of rocks of more or less familiar types which have been identified to facilitate the work of mapping and do not possess such points of interest as would justify detailed consideration in this place.

III. CHEMICAL WORK.

The following work has been done in the Chemical department. Dr. V Polla

In connection with the South Wales Coalfield, the literature concerning chemical analyses of the coals of that district has been gone through, and such analyses selected as may be of use for the proposed Coal Map. Seven complete analyses from the Rhas Las vein were made, bringing the number available, from all sources, for the map of this vein up to twenty-four: No further samples of this vein have at present been obtainable.

Five samples of coal from Mull were analysed for the Duke of Argyll, and eight from the Falkland Islands for the Colonial Secretary of the Falkland Islands.

Complete analyses were made of a Ben Ledi Grit and an Albite Gneiss for Mr. Cunningham Craig, a Hornblende Schist and a Felsite for Dr. Flett, and five ultrabasic rocks from Rum for Mr. Harker.

Such assistance in the way of qualitative analyses, etc., as was possible was given to the Museum and Field Staff.

IGNEOUS ROCKS FROM THE ULTRABASIC GROUP OF THE ISLE OF RUM.

Five specimens collected by Mr. Harker have been analysed with the following results :—

Mr. Harker. (10448). PERIDOTITE, summit of Barkeval. Composed of largely predominant olivine with anorthite, augite, enstatite, and chromite.

(10454). PERIDOTITE, slope above Abhuinn Rhangail, 1,400 yards E. by N. of Harris Lodge. Essentially of olivine with a little anorthite and chromite.

(10464). ALLIVALITE, seventy yards S. of summit of Allival.

This new name is proposed for the olivine-anorthite-rocks which make up a large part of some of the Rum mountains. In this typical example the two minerals are in nearly equal proportions, and the only other minerals are a very little augite and magnetite.

(10461). ALLIVALITE, roadside near Dornabac Bridge, N. of Harris.

A coarse-textured rock of composition intermediate between the preceding type and the true peridotites, having about three times as much olivine as anorthite. Augite is in very subordinate quantity.

(10471.) EUCRITE. 1,200 yards N.E. of summit of Allival.

Consists of abundant ferriferous olivine, hypersthene, augite, and anorthite, with some chrome-magnetite.

Dr. Pollard.

Slice No.	10448.	10454.	10464.	10461.	10471.
SiO_2	39·04	39·16	42·20	40·82	48·05
TiO_2	·36	·11	·09	·16	·49
Al_2O_3	2·89	1·11	17·56	10·66	15·35
Fe_2O_3	2·80	2·47	1·20	1·80	1·86
Cr_2O_3	·45	·61	·06	·25	·14
FeO	7·78	11·44	6·33	8·92	7·53
MnO	.24	·15	·18	·19	·28
(CoNi)O	·23	·15	·13	·11	·11
CuO	·02	·06	·04	·05	·05
CaO	2·11	·58	9·61	6·11	11·02
MgO	39·99	43·64	20.38	28.08	12.53
K_2O	·09	·16	·11	·21	·19
Na_2O	·56	·08	1·11	·58	1·26
H_2O 105°	·15	·02	·06	·16	·15
H_2O above 105 °	3·47	·78	1·13	2·00	·45
S.	·06	·04	·02	·02	·20
CO_2	Trace ?	Trace.	Trace.	Trace.	·44
Total	100·24	100·56	100·21	100·12	100·10
S. calc. as FeS_2	·11	·08	·04	·04	·38

ROCKS FROM THE LOCH LOMOND DISTRICT.

Two analyses, of a schistose grit and an albite gneiss, were made for Mr. Cunningham Craig. In a paper on "Metamorphism in the Loch Lomond district"* he points out the similarity of the two rocks.

10653. Schistose grit, of Ben Ledi group, Rudha Dubh, 2 m. S. of Tarbet.

* *Quart. Journ. Geol. Soc.*, vol. lx., 1904, p. 10.

10654. Albite gneiss, member of Highland series, Rudha Ban, 1½ m. S. of Ardlui. Dr. Pollard.

	10653.	10654.
SiO_2	77·22	65·11
TiO_2	·59	·83
Al_2O_3	10·07	15·78
Fe_2O_3	·99	1·65
FeO	2·72	4·36
MnO	·30	·24
CaO	1·10	1·34
MgO	1·17	1·95
K_2O	2·65	3·97
Na_2O	2·65	2·49
Li_2O	Trace	Trace
H_2O 105°	—	·04
H_2O above 105°	·36	1·37
CO_2	·42	·39
P_2O_5	·14	·25
S	—	·14
Total	100·41	99·91
Total Fe as Fe_2O_3	4·02	6·49

Two rocks were analysed for Dr. Flett. The first, an intrusive dyke, from Inversnaid (300 yards E. of Inversnaid Hotel, at side of road), has been described as follows :—

10075. "This rock is an orthoclase porphyry, orthophyre or orthofelsite of rather peculiar character. In the hand specimen it shows porphyritic orthoclase, and occasionally blebs of quartz and large hexagonal crystals of biotite. The quartzes are much corroded. The groundmass consists principally of felspar, which is decomposing with production of kaolin and muscovite. The scarcity of quartz in the second generation is worth remarking. The systematic position of this rock is not very clear. It is believed to belong to a group of pale coloured highly felspathic dyke rocks which are the complementary phases of the lamprophyres. Dr. Flett.

SiO_2	71·17	Dr. Pollard.
TiO_2	·19	
Al_2O_3	15·84	
Fe_2O_3	·82	
FeO	·65	
MnO	·23	
CaO	·67	
MgO	·27	
K_2O	3·96	
Na_2O	4·38	
H_2O 105°	·31	
H_2O above 105°	1·05	
BaO	·04	
CO_2	·52	
P_2O_5	·27	
S	·04	
Total	100·41	
Li_2O	Trace ?	

The second rock (10677) is a hornblende schist, the locality—W. side of railway cutting ¼ mile N. of Ardlui station, Loch Lomond; (1 inch sheet 38). The following description has been furnished by Dr. Flett :—

"This is a biotite hornblende schist—believed by Mr. Cunningham Craig to be of sedimentary origin and mapped as belonging to the Green Beds. Dr. Flett.

Under the microscope it shows green rather fibrous hornblende mixed with biotite, rounded untwinned felspars somewhat resembling the albites of the albite schists and filled with specks of hornblende, epidote, and occasional grains of garnet. The other ingredients are quartz, often in veins and strings, pyrites and iron oxides. The analysis is very like that of many diabases.

Dr. Pollard.

SiO_2	48·28
TiO_2	1·37
Al_2O_3	13·20
Fe_2O_3	2·60
FeO	11·35
MnO	·77
CaO	7·35
MgO	7·67
K_2O	2·02
Na_2O	2·63
H_2O 105°	·07
H_2O above 105°	2·14
CO_2	·91
P_2O_5	·21
S	·03
Cr_2O_3	·02
(CoNi)O	·04
V_2O_3	·05
Total	100·71

MAGNETITE WITH TINSTONE FROM ROSS-SHIRE.

Dr. Flett and Mr. C. T. Clough.

In the foliated granite gneiss of Carn Chuinneag, Ross-shire, magnetite is found in streaks and veins along two bands which can be traced for a distance of 100 and 250 yards respectively, and have a breadth of 10 and 15 yards. Probably there are other localities in which magnetite occurs, as loose blocks of it, apparently weathered out of the adjacent rock, are found scattered over the hillside. It is believed to be a basic segregation, or perhaps a series of veins in the original igneous mass, but both have been much altered by shearing, and their exact relations are somewhat obscure. It is possible that the magnetite veins really belong to the sediments of the Moine series, now converted into granulitic gneisses and mica schists. In these there are bands of heavy minerals, which indicate the original bedding, but one specimen of iron-ore from the Moine gneisses was tested in the laboratory and proved to consist of hæmatite (not magnetite) and to contain no cassiterite.

Mr. Clough intends to re-visit the district and obtain further information regarding the abundance, distribution and general mode of occurrence of the iron ores, and to trace if possible their geological relationships, but as the locality is at a height of 1,500 feet above sea level this cannot be done till the snow has melted in early summer.

A specimen of the magnetite was sent in by Mr. Clough with a request that it should be analysed in order to ascertain whether it contained any rare elements. The analyses—which are not yet completed—show that there is a varying percentage of cassiterite in the rock. Microscopic sections prove that some parts of the

specimen contain very little tin dioxide while in others it is abundant. In addition to magnetite and cassiterite, quartz, orthoclase and plagioclase felspars, muscovite, biotite and rutile occur, and these are so distributed as to give the mass a foliated structure.

Analysis of Magnetite.

SiO_2	7·97	Dr. Pollard.
Al_2O_3	·98	
Fe_2O_3	60·69	
FeO	25·94	
MnO	·16	
CaO	·59	
MgO	·26	
SnO_2	3·22	
H_2O at 105° C.	·06	
H_2O above 105° C.	·43	
Total	100·30	

Alkalies not estimated. No other elements excepting a trace of Titanium and a doubtful trace of Tungsten were found.

Sir W. Ramsay was good enough to examine two of the specimens for Radium, and reports that they "show no radioactivity whatever."

This analysis was made from chips detached from three different parts of the hand specimen, but cannot be regarded as indicating the mean composition, even of the block from which these chips were taken. Further samples, sent in by Mr. Clough, are equally irregular in composition. Some contain no tin, others only a trace, while one carries from 15 to 17 per cent. of cassiterite. Dr. Flett and Mr. Clough

Magnetite occurs disseminated through the granite in small patches and isolated crystals of small size, enclosed in the other minerals, but an examination of the microscopic sections in which it was thought likely that cassiterite might occur has failed to indicate its presence.

Apart altogether from the possible economic importance of this discovery, about which it is premature to speak, there are certain other points of interest about it to which reference may be made. It is the first recorded occurrence of tinstone in Scotland, as though this mineral is abundant in Cornwall and has also been found in Ireland, it has not been hitherto proved to accompany any of the numerous granitic intrusions in the Scottish Highlands and Southern Uplands. Moreover if the preliminary hypothesis indicated by the facts as at present known be correct, viz.—that the magnetite and cassiterite are early basic segregations from the granitic magma, the mode of occurrence is of great interest and is perhaps unique. Tinstone is mostly found either in sands and gravels derived from the wear and tear of the lodes, or in veins and impregnations accompanied by quartz, tourmaline, and chlorite. If such veins had once been present in the Carn Chuinneag granite and had been subsequently torn out and crushed during the earth movements which converted the granite into a gneiss they could not have produced

the tinstone and magnetite nodules, for quartz is com rare and tourmaline apparently does not occur. There is something unusual about these deposits, and it is hoped t the course of this year it will be possible to collect additional facts to clear the matter up.

IV.—PALÆONTOLOGICAL WORK.

Mr E. T. Newton.

The Palæontological department has received during upwards of 2,200 fossils, obtained chiefly by the offic Survey, but in part also by presentation and purcha of these have been added to the Museum collection.

Among the donations of fossils (a full account of whi found in the annual report for 1903) attention may be directed to the series of specimens from the older rocks in the neighbourhood of Haverfordwest, presente V. M. Turnbull.

A large portion of the specimens obtained by the Fossil are Coal Plants which have been placed in the hands of Mr. I for examination and to assist him in the palæobotanica has undertaken for the Survey.

The specific determination of the invertebrate fossils obt the Carboniferous Limestone and Coal-measures of the Mid South Wales, as well as those from the Jurassic rocks of th Islands of Scotland, has occupied the greater part of Kitchin's time during the year and is nearly completed. will be of value in the separation of horizons, but ther some difficult points remaining for settlement.

The vertebrate remains, including the fragmentary bu ing series collected by Mr. Clement Reid, from the Devo of Newquay, have been examined by Mr. Newton, wh determined some glacial shells from Argyll.

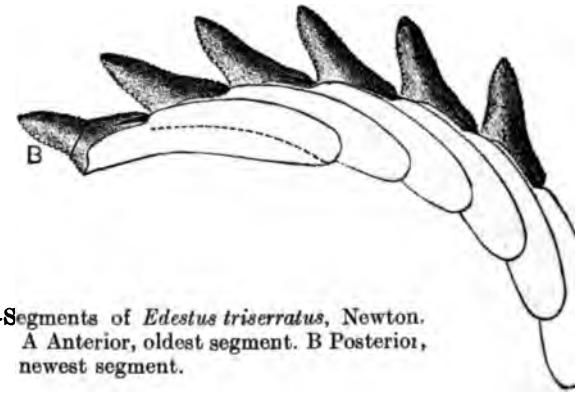

Fig. 2.—Segments of *Edestus triserratus*, Newton. A Anterior, oldest segment. B Posterior, newest segment.

Among the fossils collected by Mr. J. Pringle from t bed of the Coal-measures at Smallthorne in North St were fragments of a fish, which, when cleared from m

pieced together were shown by Mr. Newton to be a segment of one of those remarkable ichthyodorulites known as *Edestus*. Remains of similar fish have been found in North America, Russia, Japan, and Australia, but this is the first time such a fossil has been met with in the British Isles. A full account of this specimen, illustrated by a plate, has been published, but the accompanying figure will give some idea of the nature of the fossil.* Only one of the segments here represented has been found, but its form indicates that it once formed part of a series which was originally arranged somewhat as here shown. Mr. E. T. Newton.

Much of Mr. H. A. Allen's time has been occupied in the continued revision of the nomenclature of the Jurassic Mollusca, and he has now completed this task so far as concerns the Gasteropoda of the Lower, Middle, and Upper Oolites. As in former years, he has also prepared a catalogue of the type and figured specimens of this group; a most useful piece of work which will be found printed as Appendix VI. of this Summary, page 175. A similar revision of the Lamellibranchiata of the Oolites is now in progress.

The Jurassic Vertebrata are undergoing revision and re-arrangement by Mr. Newton.

In April Mr. Newton and Mr. Pocock visited the railway cutting at New Cross. The section there exposed showed the "Pebble bed," which had been noticed by Professor Prestwich many years ago† and referred by him to the basement bed of the London Clay. Now, however, fossils such as *Ostrea*, *Cyrena*, *Melania* and *Cerithium* have been found in the pebble bed itself, thus proving its estuarine character, and it is therefore more correctly associated with the Woolwich series than with the London Clay. Mr. W. Whitaker regards this exposure at New Cross as the most westerly extension of the "Woolwich pebble bed."

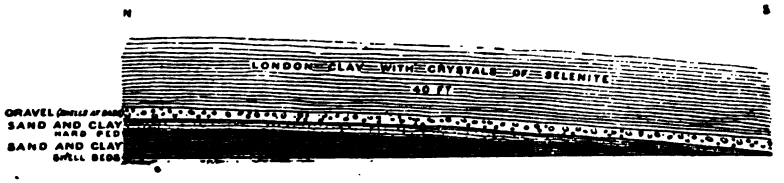

Fig. 3.—Section of railway-cutting south of New Cross Station, L.B. & S.C. Railway.

The following are the details:—

London Clay—Bluish clay with selenite.

Woolwich Beds:
- Pebble-bed (gravel) 3 feet with shells at base: *Cyrena*, *Melania*, *Ostrea* and *Cerithium*, more abundant at south end of cutting.
- Clay and sand with shell fragments 2 feet 6 inches.
- Hard bed of calcareous sandstone, 6 inches.
- Clay and sand with *Unio* and *Cyrena* in upper part, *Ostrea bellovacina?* lower down, and *Mytilus* in lower exposed part.

* *Quart. Journ. Geol. Soc.*, vol. lx., p. 1 and pl. 1. The above illustration is reproduced by permission of the Council of the Geological Society, from fig. 2, p. 1.

† *Quart. Journ. Geol. Soc.*, vol. vi., p. 261.

Mr. E. T. Newton.

In May Mr. Newton accompanied Mr. H. B. Woodward to Biggleswade in Bedfordshire to examine the rocks and fossils obtained by Mr. H. Home from the large well sinking for the waterworks of that town. The specimens were carefully examined and one series proved to be of the age of the Ampthill Clay or Lower Corallian, and as they had been obtained from a mass of strata 67 feet thick, with Boulder-clay both above and below it, the evidence was clear that this enormous block was a transported mass in the Boulder-clay. An account of this well sinking has been published by Mr. Home.*

Early in September Mr. Newton, in company with Mr. W. Gibson, visited Denby, near Derby, to examine a collection of Coal-measure fossils belonging to Mr. Mark Fryar. This series of fossils included some fine examples of *Megalichthys Hibberti*.

During November Dr. Kitchin twice visited the Dover Colliery Works in order to examine the lowest Mesozoic strata passed through in the course of the sinking and to select a representative series of specimens.

On two occasions in the month of December, Mr. H. A. Allen visited Sittingbourne to examine the recently exposed section of Brickearth, as well as the remains of Mammoth and Rhinoceros that had been found. As the section is likely to be very speedily destroyed the following particulars are recorded:—

Section exposed 1 furlong S.E. of Tong Church, Sittingbourne :—

	Ft.	In.
3. Soil	1	0
2. Brickearth	9	6
1. Brickearth worked	3	0

The upper bed of brickearth (2) is brown in colour, with a few scattered fragments of flint-gravel; the lower bed (1) is greenish grey, with much flint-gravel.

At the junction of beds 1 and 2, and within an area of eighty yards, a large number of bones of Mammoth and Rhinoceros were found. The Mammoth remains were very friable, but those of Rhinoceros obtained by Dr. Noble were in a much better state of preservation.

The following is a list of the bones found in this section :—

Elephas primigenius, Blum. A ramus of lower jaw with molar tooth; fragments of two tusks, one very much crushed, the other a better preserved proximal portion 4 feet in length; and a tibia.

Rhinoceros antiquitatis, Blum. Two molar teeth; also limb-bones probably of the same species.

The fossil collector, Mr. J. Pringle, has been occupied in the field for a large part of the year collecting specimens, chiefly from the Carboniferous Limestone and Coal-measures in North Staffordshire, Nottinghamshire, Leicestershire, Derbyshire, and North Wales.

* *Quart. Journ. Geol. Soc.*, vol. lix. (1903), p. 375.

Workers and students in Palæontology continue to make good use of the collection of fossils, and are assisted as far as possible by the officers. Mr. E. T. Newton.

The following is a list of the Museum specimens which have been figured and described during the year :—

In the PALÆONTOGRAPHICAL SOCIETY Vol. for 1903.

Cretaceous Lamellibranchia of England. Part 5.

By Mr. H. Woods, M.A.

Pecten cometa, *d'Orb.* pl. xxxix., figs. 9, 10. (Two specimens.)
———Morrisi, *Pict. and Ren.*, pl. xxxix, figs 11, 12. (Two specimens.)
——— quinquecostatus, *Sow.*, pl. xxxix, figs. 16, 17. (Two specimens.)
——— striatocostatus ? *Goldf.*, pl. xli, figs. 9, 10.
Velopecten Studeri, *Pict. and Roux*, pl. xlii, fig. 2.

Lower Palæozoic Trilobites of the Girvan District. Part 1.

By F. R. Cowper Reed, M.A.

Agnostus girvanensis, n.sp., pl. l, fig. 3.
Trinucleus Bucklandi, *Barrande*, pl. l., figs. 12–14. (Three specimens.)

British Carboniferous Lamellibranchiata, Vol. II. Part 2.

By Dr. Wheelton Hind.

Pterinopecten rigidus, *M'Coy*, pl. viii, fig. 3, 3a.
Aviculopecten tabulatus, *M'Coy*, pl. xii, fig. 2.
———————— dissimilis, *Fleming.*, pl. xiii, figs. 6, 7. (Two specimens.)
———————— semicostatus, *Portl*, pl. xiii, fig. 9.
———————— pera, *M'Coy*, pl. xv, fig. 14.
———————— perradiatus, *de Koninck*, pl. xv, fig. 17.
Pseudamusium fibrillosum, *Salter*, pl. xv, figs. 16–19. (Four specimens.)
———————— sublobatum, *Phillips*, pl. xviii, figs. 11–14. (Four specimens)

British Graptolites. Part 3.

By Miss Elles, Miss Wood, and Prof. Lapworth.

Leptograptus validus, *Lapw.*, pl. xvi, fig. 1*a–c*. (Three specimens.)
———————— latus, *Elles and Wood*, pl. xvi, fig. 5 *a–e*. (Five specimens)

In the QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY.

Vol. lix, 1903.

By Mr. E. T. Newton,

Alces machlis, *Ogilby*, pl. v, p. 80–89.

By Dr. Wheelton Hind.

Solenomorpha major, n. sp. (Text figure.) pp. 334–336

By Dr. F. L. Kitchin.

Ostrea discoidea (*Seeley MS.*) n. sp., p. 378.

V.—MUSEUM OF PRACTICAL GEOLOGY.

Mr. J. A. Howe.

The most important change in the mineral department has been the arrangement of a collection of the *Minerals of the British Isles* in the series of twelve table cases formerly occupied by the metallurgical collection. Although the ores of this country had already been separated from the foreign ores, and were kept apart as a distinctive series, there had never been a comprehensive collection of British minerals exhibited in the Museum. The specimens for the new arrangement have been selected almost exclusively from the Ludlam Cabinets and consequently the minerals previously exhibited in the Museum have scarcely been disturbed.

The " British Collection " has not been classified according to any chemical system, but is arranged on a broad topographical basis; the specimens having been so selected and juxtaposed as to illustrate as far as possible their natural occurrence, geological position and genetic relations. The object has been to regard the minerals from the natural history point of view.

The specimens in this newly formed British collection, numbering about 1,650, have already been labelled and the preparation of a descriptive handbook is in progress.

For this work the Museum has been fortunate in securing the services of Mr. F. W. Rudler and thus to utilise his invaluable personal knowledge of the specimens.

In another direction the Museum has benefited by the aid of Mr. E. J. Lovegrove, Engineer to the Borough of Hornsey, who has presented a large number of samples of ROAD STONE. These samples have been described by Dr. Flett and a selection, with photo-micrographs and details of Mr. Lovegrove's attrition tests, is now exhibited on the ground floor. It is hoped that this kind of work will be extended to the mutual advantage of Engineers and Surveyors and of the Museum.

The London Model has been temporarily removed to the St. Louis Exhibition, and its place is at present occupied by a selection of the minerals which possess special properties of radio-activity.

THE LIBRARY.

Considerable additions have been made to the Library and the Card Catalogue of Books is now available for reference.

II.—SCOTLAND.

I.—FIELD WORK.

Dr. J. Horne.

The ground surveyed in the Highlands was arranged in three districts as follows:—

1. Knapdale and the area east and west of Loch Linnhe under Dr. Peach, F.R.S.
2. Central and Eastern Ross with part of Inverness-shire under Mr. Clough, M.A.
3. District of the Small Isles under Dr. Peach, F.R.S.

Dr. J. Horne.

The Carboniferous areas in the Lothians were arranged in two districts :—

4. Western Midlothian and West Lothian under Dr. Peach, F.R.S.

5. Eastern Midlothian and Haddington under Mr. Clough, M.A.

In the West Highland District, field-work was carried on in the deer forest areas east and west of Loch Linnhe in Sheet 53, and before the close of the season, the whole of the unsurveyed ground west of that sea-loch was completed, together with a small area, near Strontian in Sheet 52. During the autumn the work was continued in the low ground of Knapdale. The Memoir on Sheet 37, Argyllshire, is now ready for publication.

In the North Highland district, embracing Central and Eastern Ross with part of Inverness-shire, the remaining unsurveyed portion west of Loch Ness, in Sheet 83 was finished, and before the close of the season the greater part of Sheet 93 was also completed. The Memoir of Sheet 83 is now in an advanced state of preparation.

In the district of the Small Isles, owing to favourable circumstances, the mapping of Canna, Sanday and Muck, together with the remaining portions of Rum and Eigg, was overtaken, and the survey of Sheet 60 is now finished.

The district Memoir on The Tertiary Igneous Rocks of Skye is in the hands of the printer and will shortly be issued. The Memoir descriptive of Sheet 70, embracing part of the Cuillins, Minginish and Soay, is in the hands of the printer, and will be issued simultaneously with that map.

After the close of field-work in the Highlands, the revision of the Carboniferous areas in the Lothians was resumed and by the end of the year the whole of the Midlothian basin included in Sheet 32 was re-examined. The coals and limestones of the Carboniferous Limestone series were traced along the west side of that basin, in the direction of West Linton; and from the Roman Camp Hill north to Musselburgh and Port Seton on the east-side. The central area occupied by the Coal Measures with the surrounding barren zone of Roslin Sandstone, was revised. The oil shale fields in the districts of Westcalder and Burdiehouse, together with the Calciferous Sandstone area south and south-west of Haddington, were re-examined. In the course of this revision many mining plans and journals of bores were examined and every effort has been made to bring the mining information up to date.

The Memoir on the Geology of North Arran, South Bute, the Cumbraes and parts of the coasts of Ayrshire and Kintyre, was published during the year.

1. West Highland District—Ardgour, Ballachulish, Glencoe and Knapdale, Argyllshire.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. J. S. Grant Wilson.
Mr. H. B. Muff, B.A.,
Mr. E. B. Bailey, B.A., } Geologists.

HIGHLAND METAMORPHIC ROCKS.

Dr. Peach. *Ardgour Area.*—This tract is a portion of the high tableland rising abruptly on the west side of Loch Linnhe and at once reaching a general level of over 2,000 feet. It is, however, deeply trenched by a system of valleys that have a general E.S.E., and W.N.W., trend, all of which are continued in comparatively low passes across the watershed, which now separates the two sets of streams flowing respectively eastwards to the Linnhe Loch and westwards to Loch Sunart and Loch Shiel.

The greater part of the area is under deer forest and thus very sparsely populated. Such a mass of high ground on the west coast entails a heavy rainfall. The water supply is therefore abundant and far exceeds the requirements of the population.

The rocks of the Metamorphic series consist of granulitic schists and gneisses of Moine type varying from nearly pure quartz-schists to muscovite-biotite gneisses, and are, for the most part, in a highly altered condition, the western portion of the area being traversed by innumerable granitoid intrusions.

In the Bealach Coire nam Muc, a low pass between Glenscaddle and the foot of Glen Gour, Mr. Wilson observed a group of rocks consisting of marble, calc-silicate hornfels, and biotite hornfels in which the original bedding planes have been preserved. The intrusion which has produced this metamorphism appears to be an offshoot of the Glenscaddle epidiorite mass. Thus, additional evidence is obtained in support of the conclusion that the Glenscaddle massif was intruded before the development of the foliation of the region.

All the schists and gneisses are intensely folded, the axial planes, of the folds being seldom vertical. The longer axes of the folds, for the most part, have the normal north-east and south-west trend, but west of the Glenscaddle massif their direction is N.N.W. and S.S.E. Such deflections are not uncommon around these older intrusions.

Messrs. Peach, Wilson, Muff, and Bailey. *Ballachulish and Glencoe Area.*—The metamorphic rocks belong probably to the following groups, which are given below in descending order.

(*c*) The quartzite.

(*b*) Ballachulish slate group consisting of black slates and phyllites with one or more bands of dark carbonaceous limestone and some quartzite intercalations. (The Black Schists).

(*a*) Grey and dark phyllites often calcareous and having a conspicuous band of yellow or cream-coloured limestone or dolomite (Appin Limestone), near its upper limit. (The Ardrishaig Phyllites). These phyllites, between Glencoe and Loch Leven, appear to graduate downwards into fine-grained quartz-schist or quartzites which may be on the horizon of the Inverary quartz-schists; but this correlation does not, at present, rest upon a sufficiently wide basis of observation.

Mr. Wilson. The general structure of the ground south and west of Ballachulish is that of a compound syncline, the various members being repeated in isoclinal folds, the longer axes of which trend N.N.E.

and S.S.W. Here the phyllites of group (a) strikingly resemble the rocks of this zone as they occur in parts of Perthshire. The slates of Ballachulish are quarried from a band in group (b) immediately underlying the little black limestone and are on the same general horizon as those of Easdale and Luing. Grey quartzite bands are seen to be intercalated with the dark slates in the Laroch Burn, which flows into Loch Leven at Ballachulish. Mr. Wilson.

The quartzite (group c) is there in contact with the Ballachulish slates and the Ardrishaig phyllites, as if separated from these two by an unconformability. It generally has a pebbly margin, which in places, becomes a conglomerate or boulder bed.

Between Glencoe and Loch Leven the relation of the metamorphic rocks to each other is not so easily determined. There is no difficulty in recognising the members of group (a), although they are often much deformed and frequently hornfelsed by igneous intrusions. The yellow dolomitic limestone (Appin Limestone) occupies the bed of the River Coe from Coe Bridge to the sea. On the north side of Glencoe, from the above point to Clachaig, Mr. Muff found a succession of beds which dip under each other on the hill slope in the following descending order. Messrs. Peach, Muff and Bailey.

4. Mica schist and calcareous phyllites with beds of impure limestone.
3. A narrow belt of graphitic schist.
2. Green and grey phyllites with quartzose bands and partings of black slate.
1. Fine-grained quartzite without pebbles.

The succession here recalls that of the Ardrishaig phyllites found on the shores of Loch Fyne, but a wider area of these rocks in the Loch Leven district must be mapped before this correlation can be fully established. Here the fine grained quartzite forms a wide belt of high ground. In the elevated area on the north side of Glencoe this quartzite is more or less permeated with, and altered by a granitoid porphyrite, which, however, appears not to have broken through the overlying phyllites and calcareous rocks which it has converted into hornfels. According to Dr. Flett some of the more complex hornfels bands contain quartz, felspar, biotite, sphene, epidote, and forsterite, and others calcite, tremolite, felspar, biotite and sphene.

Knapdale Area.—The portion of Knapdale surveyed during the season lies chiefly within the promontory situated between Loch Sween and the Sound of Jura. A few square miles of country round the head and on the east side of that Loch were also mapped. The area is part of the low plateau described in last year's Summary of Progress* where it gradually sinks southwards into the sea; the sound of Jura, Loch Sween and its branches representing valleys; and the land, the dividing ridges. The islands and skerries indicate the direction of the ridges further seawards. Messrs. Peach and Bailey.

* Summary of Progress for 1902, p. 66.

Messrs. Peach and Bailey.

The geological formations and the underground str scribed in last year's Summary* as occurring in the dist iately to the north, are likewise found here, with local m

The dark limestones associated with the Easdale slates developed in the south part of the peninsula and in D they form belts of fertile ground. Owing to the pitch these areas diminish in breadth when followed nortl each in turn disappears under the overlying members of t group. In Eilean Mor, about two miles south of Dann bed was observed, in which the grains, showing a concent ment, are almost as big as peas, strongly resembling bands of the Islay Limestone.

The area also yields important evidence pointing to formability between the quartzite series and the Ea and limestones. The pebbly limestones, boulder bed a are well represented. The Boulder Bed near the old C at Keils yields, in addition to local pebbles of slate an many of granitoid and other igneous rocks foreign to the identical with blocks found in the Islay and Garvelloc Bed."

OLDER IGNEOUS ROCKS IN METAMORPHIC SER

Dr. Peach and Mr. Wilson.

Ardgour Area.—As already indicated, this area is n permeated with igneous rocks of various ages. Among are the offshoots of the epidiorite mass of Glenscaddle, on both sides of Glengour. Another foliated igneous m observed in the high ground stretching from the head o tian River, eastwards towards the streams draining into (The rock is a foliated granite or augen-gneiss with matrix, showing flaser structure, in which are set ro phyritic crystals of pink felspar with carlsbad twinning. however, the porphyritic felspars are absent. The r resembles the well known augen-gneiss of Inchbae in E

The boundary line between the augen-gneiss and the schists is very irregular, due partly to injections, but subsequent folding. The augen-gneiss, while sharing in of the region, is foliated in the same direction as the sc rock is seen to cut some small masses of epidiorite and schist, but is in turn pierced by later dykes of that mat also traversed by aplite and pegmatite veins, some of shared in the foliation and are granulitic, while oth massive, and probably belong to the later granites.

Dr. Peach.

Tayvallich Area, Knapdale.—The resemblance of ce orites, occurring with the schists in Argyllshire, to ba Arenig age in the South of Scotland was first recogni Teall and has been recorded by members of the staff

* Summary of Progress for 1902, pp. 70-75.

reports.* But no direct evidence was obtained that any of the epidiorite masses were contemporaneous with the sediments with which they are associated, though many sills of epidiorite have been proved to be intrusive. Dr. Peach.

During last season, in the ground south of Tayvallich, where the metamorphic rocks and their associated igneous masses are only slightly, if at all, deformed, Dr. Peach obtained evidence that sheets of slaggy andesitic basalt, with marked "pillow structure" are intercalated with the Black Schist and Limestone series as well as with fragmental rocks like tuffs or agglomerates, in such a manner as to indicate that they were contemporaneous with them. He also observed a massive porphyritic felsite, intrusive at one place in the pillowy andesitic basalts and fragmental rocks; indeed, the fragmental rocks are in great part made up of dust and blocks of a similar felsitic rock, and are interbedded with the epidiorite sheets in the same coast section. The felsitic rock greatly resembles some of the blocks found in the boulder bed at Keils, and in the Loch Awe area.

OLD RED SANDSTONE.

During last season a small patch of breccia and red sandstone was observed by Mr. Wilson on the eastern headland of Cilmalieu Bay, on the west shore of Loch Linnhe, where the strata rest unconformably on the schists and their granitic intrusions and have a gentle dip towards the S.W. The pebbles found in the breccias are composed of the local schistose rocks, granite and pink felsite. Though no fossil evidence to prove their age has been obtained, the rocks of this outlier greatly resemble those of the basement members of the Orcadian Old Red Sandstone of the Moray Firth Basin. Mr. Wilson

Lower Old Red Sandstone Volcanic Rocks.

Glencoe area.—A small area of these rocks was mapped during the season by Dr. Peach and Mr. Muff in Glencoe. The geological age of these rocks was determined in 1902, and referred to in last Summary of Progress. The general succession has already been given by Mr. Kynaston in the Report of the British Association for 1902.† Messrs. Peach and Muff.

On the north side of Glencoe the volcanic rocks are separated from the underlying schists by greenish grey conglomerate, sandstone, and shale. In places, the conglomerate is like a *remanie* breccia of quartzite, and vein quartz, but for the most part the boulders are large and well rounded, being set in a sandy matrix. Some consist of andesite like the overlying lavas, showing that the

* Summaries of Progress for 1899, p. 62 (Teall and Symes), 1900, pp. 32-35 (Kynaston); Ibid. pp. 41-42 (Hill); 1901, p. 129 (Peach, Wilson and Muff.)

† Brit. Ass. Report (Belfast) 1902, p. 602.

Messrs. Peach and Muff.

volcanic conditions had already existed for some time in the region and that the lavas had been exposed to subærial denudation near at hand. The most striking boulders, however, are of granite, diorite, and other granitoid rocks, many of which are so large as to suggest the idea that they are not far from their parent source. As most of them are isolated in sandstone it is not improbable that they may have been floated into their present bed. These sediments are succeeded by a pile of basic andesitic lavas and agglomerates with a few thin intercalations of reddish shale between some of the flows. The basic andesites are succeeded by a thin zone of rhyolitic lavas and agglomerate which have a much greater development on the south side of the glen, and these are in turn overlaid by andesitic lavas and agglomerates.

Mr. Muff.

On the south side of the glen the basic andesites of the lower zone rest unconformably on the denuded edges of the schists and comprise many lava flows, between which, thin beds of agglomerate or red shales are occasionally found. These flows show "pillow structure" in places. The pile of andesitic lavas appears to thin out when traced eastwards, owing both to the uneven floor upon which they have been laid down and also to the overlap of the succeeding rhyolites. The latter, on the other hand, appear to thicken eastwards. On Stob Coire an Lochan the rhyolites are succeeded by a coarse agglomerate, composed mostly of andesitic fragments, but containing locally blocks of rhyolite and occasionally pieces of quartzite. Traced eastwards into Glen Coire Gabhail, the materials of the agglomerate become finer, and beds of shale appear, till eventually it is entirely represented by green shale. The summit of Stob Coire an Lochan and Bidean nam Bian is composed of a thick series of lava-flows of hornblende-andesite in which a hexagonal columnar jointing is well developed.

Mr. Peach.

These rocks have been truncated towards the west by a powerful fault which crosses the valley at Loch Triochatan in a N.N.E. and S.S.W. direction and brings them down against the schist and granite.

The unevenness of the floor on which these rocks rest is very marked upon the north side of the valley, for on the very crest of the Aonach Eagach, at a height of nearly 3,000 feet, the quartzites appear at the surface not more than a mile eastwards from the western margin of the andesites, although the latter dip more or less continuously in that direction.

NEWER INTRUSIVE IGNEOUS ROCKS.

Messrs. Peach, Wilson, Muff, and Bailey.

Ballachulish Area.—Mr. Wilson mapped the eastern margin of the granite massif of Ballachulish which has already been described in a former report.* The contact effects of the granite upon the schist are very marked especially upon the impure calcareous phyllites which are converted into calc-silicate and biotite-hornfels.

* Report of Director-General, Geological Survey for 1896, p. 21.

The granitoid porphyrite, which invades and alters the quartz-schist, andesitic lavas and agglomerates, in the Glencoe district, has already been mentioned, but it appears to occur in much greater mass in the ground immediately to the north of that surveyed during last season. Messrs. Peach, Wilson, Muff, and Bailey.

All the above rocks are traversed by dykes of felsite, hornblende-porphyrite, and lamprophyre running in a N.N.E. and S.S.W. direction. They are especially numerous in Glencoe on both sides of Loch Triochatan.

Ardgour Area.—Part of the quartz-diorite or tonalite mass of Strontian was mapped by Mr. Bailey, which, with its more basic inclusions, shows a slight foliation. In the small surveyed area it makes a sharp line of junction with the schists, into which it appears to have been intruded subsequent to their folding and foliation. For some distance west of the Linnhe Loch the schists are more or less permeated with a pink or red biotite granite which occurs in greatest mass near Glengalmadale and Cilmalieu, and may yet prove to be a more acid phase of the tonalite of the Strontian massif.

Veins, sills, and dykes of a fine-grained grey micro-granite or aplite traverse the schists of the region, the augen-gneiss and the tonalite. Distributed in the same manner as these aplites, though less abundantly, is a dioritic rock, distinguished by its large hornblende crystals which are associated with quartz and orthoclase and an acid plagioclase. This rock was not observed to cut the tonalite. A still later set of intrusions occurs in the form of dykes of quartz-felsite which run for miles in a general east and west direction, and, with the exception of basalt dykes, probably of Tertiary age, are the youngest intrusions in the district. These newer granites probably belong to the same general date of intrusion as those of the Cruachan massif.

TERTIARY INTRUSIVE ROCKS.

Ardgour Area.—The schists, together with the various igneous rocks which pierce them, are traversed by dykes of basalt in a N.W. and S.E. direction, which are presumably of Tertiary age. A peculiar interest attaches to these later dykes in the present region as Mr. Bailey found that one which crosses Garbh Bheinn between Glen Gour and Glen Tarbert is traversed longitudinally by veins of barytes. This dyke can be traced into the one which, at the Strontian Mines, bears the vein long worked for galena and afforded the famous Strontianite. The Strontian mines formerly so prolific were closed for a number of years. Of late, operations have been resumed and a shaft is being sunk to enable a deeper portion of the vein to be reached.

FAULTS.

The Great Glen Fault flanks the S.E. margin of the Ardgour area which is washed by the waters of the Linnhe Loch. One

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branch of the fault leaves the Loch near Cilmalieu and after a course of about three miles, in a N.W. direction passes out to sea again at Inversanda. Still another branch of the fault, running more or less parallel with the foregoing, cuts off the Cilmalieu granite mass from the schists to the N.E. The above rocks, for a mile or so inland from the Linnhe Loch, are, therefore, much disturbed, shattered, and reddened.

PLEISTOCENE AND RECENT DEPOSITS.

Ardgour Area.—The evidence observed on the highest mountain tops points to the conclusion that, during the great glaciation, the ice must have crossed the area in a general direction from north to south, quite independently of the intervening valleys. West of a line drawn N. and S. through the centre of the area which is east of the main watershed, the striæ gradually swing round towards the W. till near the margin of the area they show movement towards the W.S.W. or even W. in some cases. The highest point in the plateau, Sgor Domhail (2,915 feet) is striated in an E.N.E. and W.S.W. direction within a short distance of its summit.

The later phases of the glaciation are well illustrated by striæ conforming generally to the natural slopes of the ground and by the usual phenomena of lateral and terminal moraines, as may be seen in Glen Tarbert on the road between Inversanda and Strontian.

No trace of the 100 feet beach was found, from which it is reasonable to infer that, in this area, the shore was occupied by glacier ice, during the period of its deposit elsewhere. This inference obtains support from Mr. Muff's observations regarding the 50 feet beach deposits near Cilmalieu, where an incomplete terminal moraine, formed by a glacier which had descended from the neighbouring corries, had reached for a short distance the level of this raised beach. Beyond the moraine, the usual sloping terrace of the beach is formed of gravel, sand, and a greenish silty clay, while the marginal face of the moraine is steep and concave, as if cut out by the sea. In Glengalmadale, a little to the S.W. of Cilmalieu, Mr. Muff found morainic drift intercalated with the shingle of the beach. Above this point the beach terrace disappears, the modern alluvium being at a lower level than the terrace and the first moraine seen on the floor of the valley occurs half a mile further up. This evidence points to the conclusion that the 50 feet beach was here contemporaneous with the valley glaciers.

Messrs. Peach and Bailey.

Glencoe Area.—On the ridge between Glencoe and Loch Leven, at heights of from 2,900 to over 3,000 feet, striæ were observed pointing W. 5° N. to W. 17° S. This indicates a period when an ice-sheet marched westwards across this area almost independently of the surface configuration. Additional evidence of this movement is afforded by the distribution of large boulders of the Rannoch Moor diorite on the ridge itself and in patches of Boulder-clay occurring in the high corries of the ridge.

Mr. Muff. The hill tops on the south side of Glencoe are so much covered with shattered rock that no evidence beyond a general rounded aspect of the crags was obtained regarding the great glaciation.

Messrs. Peach, M and Bailey The phenomena of the later glaciation are everywhere apparent in the valleys, as indicated by the striæ, and by the moraines. Glencoe appears to have long acted as one of the lines of drainage for the *mer de glace* that must have filled Rannoch Moor during this period. The later phases of this glaciation are well illustrated by a marked series of moraines in the side valleys even up to the recesses of the corries. The freshness of the striated surfaces and moraines in the corries suggest the presence of local glaciers in very recent geological times.

Dr. Peach and Mr. Bailey *Tayvallich Area, Knapdale.*—The evidence afforded by the glacial striæ which are abundant all over the district, together with the distribution of the boulders, shows that the area has been crossed by ice which moved in a general S.W. direction, varying in the promontory west of Loch Sween from S. 30° W. to W. 30° S. Small patches of Boulder-clay also occur near Kilmichael-Inverlussa, near the head of Loch Sween, on the promontory of Keils, and on Danna. All the above phenomena are referable to the period of the great extension of the ice. A few moraines, occurring in the glens to the east of Loch Sween, well inland from the coast and high above sea level, may be cited as relics of the later glaciation. It is, therefore, evident that the ice during the later stages of the glacial period did not reach the sea in this area. Hence the 100 feet raised beach is well developed in the region and is especially well seen in Danna. The 50 feet beach is of still wider extent, and is marked by a conspicuous cliff feature, though its inner margin does not usually rise above 35 feet. These raised beaches and the patches of Boulder-clay form most of the arable land of the area. The margins of all the raised beaches are marked by conspicuous lines of large stranded boulders, which admirably exhibit the phenomena of old storm beaches and gravel spits in the more exposed situations.

ECONOMICS.

Mr. Wilson *Ballachulish Area.*—The chief industry of the district is slate quarrying, which has been extensively prosecuted, though temporarily stopped during last season. The original quarry has been wrought to a great depth, but it is generally believed that the floor of the quarry is underneath the folds that carry the best slates. A marble quarry was opened some years ago on an outcrop of the "Appin Limestone" near the Laroch Burn, a little south of the village of Ballachulish. The marble has a very delicate rose colour, but it is difficult to polish owing to the presence of silicates. Hence quarrying has been abandoned for some years and many blocks are left near the spot.

Dr. Peach. In the neighbourhood of the slate quarries, there is an extensive population. The lower part of Glencoe is sheep ground, and the rest of the area is under deer forest, these tracts being thinly populated.

Tayvallich Area, Knapdale.—Slates were quarried for a few years on the shores of the Linnhe Mhurich, a branch of the Linnhe Loch at Tigh Mhullin about two miles south of Tayvallich. The bands worked were thin beds of silky grey slates interbedded with more quartzose and calcareous bands in the Ardnoe group of the quartzite series. The quarry was abandoned because they were practically wrought out. The slates appear to have been thin and not of such good quality as those derived from the Easdale slate group.

Limestone is still quarried and burnt for lime in Danna at a jetty on Loch na Cill. It is used for local purposes, and a few small shiploads are occasionally despatched to other places along the coast.

Peat occurs in a few of the hollows and is worked by some of the farmers, but coal is more generally imported.

2. Central and Eastern Ross, with Parts of Inverness-shire.

Mr. C. T. Clough, M.A., District Geologist.
Mr. L. W. Hinxman, B.A.
Mr. E. H. Cunningham Craig, B.A.
Mr. C. B. Crampton, M.B., C.M. } Geologists.
Mr. E. M. Anderson, M.A., B.Sc.
Dr. J. Horne, F.R.S., (Acting).

HIGHLAND METAMORPHIC ROCKS.

Mr. Clough. *Diebidale and Carn an Liath-bhaid Area* (Sheet 93).—For a distance of twelve miles along the N. and N.E. margin of the great mass of older igneous rocks in this area, there is a belt of rock less than a mile in breadth, partly hornfelsed and partly schistose, which seems to have been originally of a semipelitic character, composed partly of sandy and partly of muddy sediment. Both in Diebidale, and also near Cnoc na Tuppat and Coire Beg, the rocks of sedimentary origin dip steeply below the foliated igneous mass; but at Carn Bhren they sometimes appear to dip under, and sometimes over it.

The Diebidale semipelitic belt, above referred to, contains a good deal of rock composed of thin alternating laminæ, some of siliceous and the others of pelitic character. The rock has been hornfelsed and has in parts entirely escaped the subsequent shearing movements, the siliceous laminæ still displaying the original rounded outlines of many of the clastic grains. The belt also includes many outcrops of white quartzite, or quartz-schist, which are unlike the siliceous rocks farther north.

Mr. Clough.

There is no sharp line between the hornfelsed rocks and the schists in the semipelitic belt, but the main areas of each are roughly separable. Both in Diebidale and Cnoc na Tuppat the hornfels is separated from the foliated igneous rocks by a band of garnetiferous mica-schist, with garnets, which, on the N.E. side of Cnoc na Tuppat, have been considerably elongated and repeatedly cracked at right angles to their length. The direction of elongation is the same as that of the clastic grains in the siliceous schist which occurs a few hundred yards W. of Diebidale Lodge, a schist which is on the north side of the semipelitic belt. Many of the hornfelsed rocks are crowded with small spots or "knoten," and in the sheared portions of the band these spots become flattened and elongated into parallel ribbons. These deformed spots are well seen close to the N. margin of the band, half a mile W.S.W., of Diebidale Lodge, and the direction of elongation in this locality is the same as that already mentioned.

On the north side of the Diebidale semipelitic band, and dipping apparently steeply under it, comes a broad belt of siliceous schist mixed with some thin seams of pelitic schist, which, on the N. side of Glen Calvie, is nearly two miles broad. Many of the pelitic seams are full of deformed spots, and it is clear that these seams must have been thermo-metamorphosed and subsequently sheared. Some of them are more than two thirds of a mile from the foliated igneous mass, and in places where the adjacent siliceous schists show no evidence of thermo-metamorphism. In one band, sometimes half a mile broad, within the Glen Calvie belt, indications of clastic grains are common, but increase in a westerly direction towards the pebbly schist described last year by Dr. Crampton. In the crags nearly half a mile slightly S. of E. of Dunan Liath there is a zone, apparently 50 or 60 feet thick, which contains seven or eight seams, each a few inches thick, which are full of pebbles, from half an inch to an inch and a half long. Some of the larger pebbles are finely granular and resemble quartzite, while others are of a reddish quartz and show little or no evidence of granulitic structures. A few bear some resemblance to red jasper. Many of the smaller clastic grains are of blue opalescent quartz, or of red felspar. This zone is very false-bedded and shows but little evidence of schistosity. Outside it there are exposures of more schistose granulitic beds containing laminæ in which magnetite and grains of epidote, both heavy minerals which would be expected to fall together in the course of sedimentation, are common. The magnetite appears to have been re-crystallised and sometimes forms a matrix in which round grains of quartz lie. The laminæ in which the magnetite is specially abundant are lenticular and often form small shallow basins, from two to ten inches long and less in breadth, which probably mark little hollows in which the heavier sediments settled at the time of deposition. Their concave surfaces face upwards, so that it is probable that the beds here, which dip S.S.E., at about 60°, are not in an inverted position.

Mr. Clough. North of the Glen Calvie belt of schists there is a band of semi-pelitic schist, with a maximum breadth of 330 yards, which dips below the siliceous schist on the south. It contains many thin siliceous seams which are rich in zoisite, garnet and hornblende, and bears a considerable resemblance to the pelitic schist or gneiss (muscovite biotite gneiss) which occurs near the head of Gleann Beag (Summary of Progress for 1902, p. 85). Near the margins of this thin belt, and for some distance outside it, there are bands of albite schist, some of which are of a tolerably siliceous character, but most of them have probably been formed out of sandy shales.

Dr. Crampton. *Beinn Tharsuinn (Deanich), Kildermorie Forest, and Strath Rusdale Area.*—The quartzo-felspathic gneisses of the Moine series approach the N.W. boundary of the older igneous rocks at Beinn Tharsuinn, and seem there to possess much the same characters as many schistose rocks which are at a much greater distance from this boundary, but some thin laminæ of more pelitic character still show indications of their former hornfelsed condition. Nowhere east or south-east of the above locality are these quartzo-felspathic rocks in contact with the granitic rocks at the surface, excepting in one area a little west of Beinn nan Eun, for a length of about half a mile.

On the N. side of Beinn Tharsuinn the siliceous rocks form a continuation of the pebbly schist described last year from Beinn a' Chasteil and the neighbourhood, and they frequently show pebbles of quartz and felspar. Pebbles are also found in bands of siliceous rock intercalated along the margin of the pelitic zone on the east side of the foliated granite mass, and they are particularly well seen at the east extremity of the ridge called Sgor a' Chaoruinn lying to the south of Loch a' Chaoruinn. These siliceous bands have retained in a wonderful degree their original sedimentary character, and show in their bedding planes what appear to be original surface markings.

The mica-schist and hornfels of pelitic character form a belt, usually a mile wide, along the eastern margin of the older granite mass from Meall na Cuachaige to Kildermorie and the west side of Meall nam Bo, where it is displaced by a fault which shifts the outcrop westward to Meall a' Chaoruinn. From Meall a' Chaoruinn the band runs to Beinn nan Eun, where it leaves the margin of the granite, and apparently dies out before reaching Abhuinn Beinn nan Eun.

North of Kildermorie the boundary of the hornfels area has been approximately defined, but sheaves of movement planes are common throughout the hornfels, and many different degrees of schistosity can be found in close proximity. A typical hornfels is in this district never found in direct contact with the older granite. The rocks so situated have at any rate a well marked schistosity.

The general strike of the rock bounding the older granite mass is more or less parallel to, and frequently follows small sinuosities of the margin, and the dip is usually at high angles and often

towards the granite. In some places, veins from the granite cut the rocks in all directions, but the small outlying masses of granite are generally lenticular and parallel to the margin. Dr. Crampton

South of the fault passing from Loch Morie to Meall a' Chaoruinn, the hornfels and the pelitic schist are much mixed together. In this area there is a hornfelsed rock containing pseudomorphs after crystals of chiastolite which have been examined by Dr. Flett, who finds that they consist essentially of shimmer aggregates of muscovite, mixed with a little biotite and small opaque grains which are most abundant near the centres. The hornfelsed rock referred to, forms two bands, with outcrops about 100 yards and 50 yards wide, which have been traced for some distance. In one place near Loch a' Chaoruinn it has undergone mechanical deformation, and passes, with gradual disappearance of the crystal-like bodies mentioned above, into a garnetiferous mica schist.

The only important fault in this area is a continuation of the W.N.W. one, which, as reported before,* throws the Old Red Sandstone against the schist in the neighbourhood of Boath. This fault is seen in a cliff on the N.E. side of Loch Morie, about three-quarters of a mile from the foot, whence it crosses the loch to a little south of Meall nam Bo and onwards to Meall a' Chaoruinn. On the downthrow or S.S.W. side, all the recognisable rock bands are shifted about half a mile farther west than on the N.N.E. side.

Strath Rannoch and Loch Nan Amhaichean Area.—The Moine schists are here mostly of a siliceous character, but bands of semi-pelitic rock occur at the margin of the older granitic mass on the north of Carn Loch nan Amhaichean, on the east of Loch nan Amhaichean, and near Loch Coire Feuchain. On Meall nan Sac, a mile and a half W.N.W. of Loch Coire Feuchain, the rock next the foliated granite, belonging to the Inchbae mass, is chiefly a massive siliceous schist, and in the space between these localities the margin of the granite seems to have crossed from one stratigraphical horizon to another. Messrs. Clough and Anderson.

The pelitic rocks are, in places, in a partially hornfelsed condition, and show either deformed "knoten" or, more rarely, good crystals of andalusite. On the south side of Carn Loch nan Amhaichean some of these crystals are more than an inch long. When in a schistose condition the pelitic rocks are frequently garnetiferous, and sometimes contain aggregates and strings of garnet.

In the siliceous schist which adjoins the granite in Meall nan Sac, there are numerous thin seams which contain pebbles of quartz and of felspar, some of them an inch and a half long. Many of the pebbles are granulitic throughout, and occasionally it is seen that their long axes are lying almost at right angles to the bedding planes.

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* Summary of Progress for 1901, p. 114.

Messrs. Clough and Anderson.

Near the S. side of Loch nan Gobhlag, there are epidotic, siliceous, or somewhat pelitic schists, containing pebbles of quartz which have been much squeezed and drawn out. In their deformed state some of these quartz pebbles are six or seven inches long, though they are close to pebbles of felspar which show no appreciable deformation and which are remarkably free from granulitic structures. Small grains of epidote and small octohedra of magnetite are very abundant in certain laminæ; indeed magnetite makes up the bulk of certain layers an inch thick.

Even longer than the quartz pebbles are some pale pink finely granulitic streaks. A careful examination of these streaks was made, in view of the great contrast in form between them and adjacent pebbles of felspar. Small blebs of quartz were noticed macroscopically in several of them, and it seems probable that they all represent pebbles, either of quartz-porphyry or of aplite. Dr. Flett states that the matrix of some of these highly sheared pebbles consists essentially of a granulitic aggregate of quartz and orthoclase, together with a little microcline and plagioclase. The felspar pebbles which have been sliced consist of microcline or microcline-perthite. One of the pebbles consists of graphic granite with coarsely cross-hatched microcline. Pebbles of quartzose granulite, approaching granulitic quartzite in character, are common, and have probably all been derived from sedimentary rocks. Some epidote veins cross the bedding of the rock, but perhaps most of the epidote grains are of detrital origin, like those already mentioned in the pebbly schists near Dunan Liath (District of Diebidale). Epidote also occurs as grains in the felspar of the sheared quarz porphyry pebbles, and in some other pebbles which consist mainly of quartz.

Mr. Anderson.

Area between Corriefearn and Garbhairidh.—The Moine schists are mostly siliceous, and usually flaggy in character. In some sections an alternation of lighter and darker bands is seen, the darker bands being marked by an abundance of biotite. The strike is very uniform in a north and south direction, and the limbs of the folds usually dip steeply to the east, but sometimes this dip is reversed. In the bed of the burn rising from the Cnoc Leathad na Siorramachad, and running towards Garbhairidh, the schist frequently contains drawn-out quartz pebbles, sometimes an inch in length. Along the same burn are several small dykes or sills of somewhat basic character, and usually foliated with the schist.

Mr. Hinxman.

Area between Strathgarve and Loch Glass.—This area is for the most part occupied by the crystalline schists of Moine series, and is in geological continuity with the areas already mapped to the north and south. The two chief members of that series,—the pelitic, or muscovite biotite gneiss, and the siliceous or psammitic schists,—are represented in the area, and exhibit their usual lithological characters.

The mountain mass of Ben Wyvis is mainly composed of coarse pelitic (muscovite-biotite) gneiss, which is brought up on what

appears to be a large compound reversed anticlinal fold, whose limbs dip to the south-east. The complex nature of this fold is apparent in the eastern corries of the mountain, on whose precipitous rocky walls the rapid alternation of the gneiss with the overlying siliceous rocks along minor anticlinal and synclinal folds is finely displayed. Mr. Hinxman.

The ground to the west, between the escarpment of Wyvis and Allt Coire Feuchain, is almost wholly occupied by the siliceous members of the Moine Series, the most quartzose type alternating along certain lines with rocks of more micaceous or semi-pelitic character. A belt of dark biotite-schists and biotite-muscovite-schist crosses the valley about a mile above the head of Loch Glass, and with these rocks is associated a thin band of zoisite hornblende-granulite. Similar dark biotite-schists occur on the Queen's Cairn and above Lochan Driogan.

The siliceous rocks in this area are arranged in apparently simple anticlinal and synclinal folds of considerable amplitude. The deep hollow which contains the waters of Loch Bealach nan Cuilean occupies the crest of one of these broad anticlines.

The apparent simplicity of the structure is, however, in all probability, misleading, and there is more reason to assume the existence of a considerable amount of repetition due to minor isoclinal folds, although the presence of such folds cannot be so readily detected among these homogeneous rocks. Distinct pebbly bands have been observed at several localities, especially on the east side of Loch Bealach an Cuilean, and on the slopes of Carn Mor. In both these places they occupy a position near the crest of one of the major anticlines, and are thus possibly on the same horizon.

OLDER INTRUSIVE ROCKS.

There are two important masses of older igneous rocks in the metamorphic series of this region (Sheet 93), portions of which have been surveyed in previous years. The larger one, which may be named after Carn Chuinneag, extends for 12 miles from Carn nan Aigheinn in an E.N.E. direction to Cnoc an Liath-bhaid; its breadth in the centre being about 5 miles. The smaller mass includes the well-known exposure of foliated granite or augen-gneiss at Inchbae, and is about 5 miles long and less than 3 miles broad. During last season the remaining portions of these granitic masses were mapped and the contact metamorphism met with has been referred to in the previous paragraphs. Important evidence has been obtained proving the existence of basic rocks in the Carn Chuinneag mass, which, together with the rocks of granite type, have undergone marked deformation. Mr. Clough

Diebidale and Carn an Liath-bhaid Area. When the rocks of the Carn Chuinneag mass are well foliated, the foliation is generally parallel to that in the adjacent schists. In many places, however, as near Leaba Bhaltair, there is no distinct plane foliation, but a linear foliation or rodding, in which the exact direction of the rods is not

Mr. Clough. always well defined. In a few places neither plane fol rodding can be discerned. This is the case, for instance, the basic masses in Diebidale and in the marginal granit Carn an Liath-bhaid. In the last mentioned hill the rc N.E. side of the unfoliated granite is a pelitic hornfels wl to have escaped shearing as much as the granite. In the of Carn Bhren foliated granite is seen lying almost h over pelitic hornfels. The foliation in the igneous rock at right angles to the line of junction, and parallel to a less distinct foliation in the hornfels. In various other even at some distance inside the edge of the igneous mass, be proved that the foliation planes must be secondary In Diebidale Burn, slightly E. of S. of the old lodge, there thin granitic strings within a basic rock. The strings sharply folded, and foliation planes cross them in a directi to the axial planes of fold, and continue into the basic some localities, *e.g.*, on the roadside rather more than h S.W. of Carn Dubh, the foliation planes in the granit have been folded and crossed by a later strain slip foliatio

Most of the basic rocks in the igneous mass have co before the more acid. Thus the diorite and hornbl which are found in various places along the N. margi Beinn Tharsuinn and Abhuinn Shalachie, are injected by granitic strings. The diorite is of two types, and the p acid variety, containing many blebs of blue quartz, frequ tains inclusions of the darker type in which no free quartz So, too, the granitic rocks near the head of Diebidale ar into two varieties, and the one which contains the most frequently cut by the other.

The granitic rocks in Diebidale and in Carn Chuinneag a rule contain conspicuous felspar augen, and in some pla instance, in the little burn 400 yards slightly S. of W. of dale Lodge, the rock is very fine-grained, and should p regarded as a foliated aplite. Near Lochan a' Chairn, a N.E., types with many large phenocrysts of felspar ofte Carlsbad twinning, are most abundant, and in places ar in sub-parallel bands. In one variety these phenocryst but two inches long, and without any clear deformation lation, though the free quartz is entirely in the form of parallel rods.

A representative of the last mentioned type is preserv the margin of the mass at Carn an Liath-bhaid, in a condi is almost free from shearing. It possesses a fine grain felspar crystals in varying abundance, and blebs of bl some of which show a tendency to idiomorphism, while o rounded outlines diversified by little bays and creeks v eaten out by the magma. It is such blebs as these w probably given rise to the rods of granulitic quartz in t rock.

Mr. Clough.

Within the pink granitic rocks about half a mile S. of old Diebidale Lodge, several foliated bands occur which contain many crystals and strings of magnetite, sometimes as much as six inches broad, as well as garnets, many large flakes of biotite, and a white plagioclase felspar. The bands are not sharply defined, but seem to pass gradually, through transition zones, a yard or two wide, into the surrounding rock. They are several hundred yards distant from the nearest recognised exposure of altered sediment. Some of the strings which are rich in magnetite have been found to contain also a variable proportion of cassiterite—a mineral which had not previously been detected in Scotland. They, and the associated rocks, will shortly be further examined in the Field, and in the meantime some additional particulars concerning their mode of occurrence, etc., are given in the Appendix.

Mr. Clough and Dr. Crampton.

Two bands of granitic gneiss, one on the E. side of Carn Chuinneag and the other between Carn Chuinneag and Leaba Bhaltair, contain conspicuous black crystals, which Dr. Flett found to be riebeckite. In the first mentioned band ægirine is also found, and it is probable that it occurs in the other too.

Mr. Clough.

In various localities adjoining the masses of diorite and hornblende-schist, as, for instance, in a small burn 1,000 yards W.N.W. of Leaba Bhaltair, and near Creag Illie, we find banded gneisses, composed of thin alternating sub-parallel rods and laminæ of granite gneiss and hornblende-biotite schist, which closely resemble portions of the Lewisian gneiss of West Sutherland. The foliation planes and rods in these banded rocks sometimes cross the laminæ. The abundance of biotite—a mineral which is rare in the adjoining exposures of unsheared diorite—suggests that the parallel granitic laminæ may represent granitic veins which were once irregularly intruded into a diorite, and that a pressure which squeezed the veins into parallelism led also to the development of biotite out of hornblende. But the cross sections of the rods do not suggest that the rock has been much squeezed, and it seems possible that these banded gneisses may represent portions of igneous material in which the granitic and more basic magmas were mixed together, and flowed together in parallel bands, before the consolidation of either. But no doubt they must have been modified subsequently to some extent by dynamo-metamorphism.

Many dykes of hornblende-biotite schist, which are the latest intrusions in the Carn Chuinneag igneous mass, are well seen in in the granitic rocks half a mile E.S.E. of Mullach Creag Riaraidh. Their average breadth is 3 or 4 feet, and their general direction in this locality is nearly E. and W. They generally make little gulleys in the granitic rock, and are always well foliated parallel to their sides. The granitic rocks are often seen to be much more finely foliated along the margins of the dykes, and parallel therewith, than further off, and it is clear that the dykes have formed lines of weakness along which an unusually strong shearing movement has proceeded. Thus it happens that dyke rocks have

gh. often a more sheared and older aspect than the rocks which they traverse.

In a few places, dykes of a hornblende-biotite schist occur within the earlier large basic masses. In the Diebidale Burn, N. of Creag Illie, the early basic rock is cut by three or four granitic veins, but these all stop bluntly at the side of a later basic dyke, which contains more biotite and is more thoroughly foliated than the early basic rock.

The Moine schists some distance off the granitic mass are traversed by a good number of thin basic sheets and dykes, most of which are in the form of hornblende-schist.

ıp- *Kildermorie Forest.*—Several different types of rock, varying in acidity and coarseness of grain, are found within the granitic mass, and the degree of reconstruction due to dynamo-metamorphism varies greatly in different parts. The commonest type consists of coarse augen-gneiss. The whole of the south-eastern margin consists of this coarse type, which can be followed in a wide band, often half a mile broad, to Carn an Lochan and Creachan an Fhioda, and runs thence to the south of Mullach Coire na Gaoithe, Mullach Coire Preas nan Seana-char, and Carn Breac, where its outcrop is apparently shifted to the north-west by the Loch Morie fault. To the north and west of this band a fine-grained type prevails, but rocks of the coarse type frequently recur. The fine-grained type, which is best seen on Carn Chuinneag and the burns running south from the watershed, is usually well foliated and in places so finely granulitic that it resembles a Moine schist.

Several exposures of basic rock of igneous origin occur in the great igneous mass to the south and south-east of Beinn Tharsuinn. In the small burn flowing from Beinn Tharsuinn into Diebidale, lumps of basic rock, sometimes angular and sometimes rounded, lie embedded in granite and frequently penetrated by granitic strings. In places, the basic rock shows no clear foliation, while in others foliation is distinct, and the basic and acid materials are drawn out into long parallel strings and lenticles. Blebs of blue quartz are commonly seen in the basic rock when the foliation is indistinct, and these have a close resemblance to the quartz blebs in the veins given off from the granite where no sign of foliation is present.

Thin intrusive bands of hornblende-schist are not uncommon in the granite, but have not been seen in the coarse granite near the eastern margin.

ugh *Strath Rannoch Area.*—The granitic rocks which belong to the Carn Chuinneag mass extend S.W. to within a mile of the keeper's house at Strathrannoch, where they end against Moine schists and Old Red Sandstone. They are very free from basic inclusions, are coarse in character, with felspar crystals often an inch long, and only obscurely foliated as a rule. The margin of the granite is almost always parallel to the strike of the adjacent schists; and the foliation in the granite is also often parallel to this border.

Mr. Clough and Mr. Anderson.

The granitic rock of the Inchbae mass is well exposed in Strathrannoch Burn, for about a mile above Inchbae, where it consists of well-foliated gneiss, with many large augen of orthoclase felspar, some of them 2 inches long. The first foliation is folded in places and crossed by a second strain slip foliation. On Meall nan Sac and for half a mile east, the granitic rock is fine-grained and without augen, and mixed with some bands of crushed and granulitised pegmatite, a type of rock which does not seem to occur often in connection with the granite either of the Carn Chuinneag or Inchbae mass.

Mr. Hinxman.

The relations of the foliated granite to the surrounding schists are also well seen on the summit and northern slopes of Carn Ban, 2 miles N.N.E. of Inchbae Lodge. The margin is a complex one, and presents a plexus of igneous and metamorphic rocks.

The usual contact phenomena of the augen-gneiss can be observed where it is in contiguity with the originally more argillaceous members of the Moine Series. These have been altered into garnetiferous sillimanite-biotite-hornfels, with an occasional sporadic development of andalusite crystals.

Dr. Horne

Area between Dochfour and Moniack Burns, Inverness.—Almost the whole of this area is occupied by crystalline schists of two types; one composed of granulitic biotite gneiss, usually coarse-grained, with numerous quartzo-felspathic folia and "eyes" of pegmatite, the other of fine-grained flaggy siliceous schist or quartz-biotite-granulite. The rocks of the former type are well seen in the Dochfour Burn, the upper part of the Moniack Burn, and on the hilly ground south of Lentran, where the abundance of quartzo-felspathic and granitic material, in strings, knots and veins, is the characteristic feature of the group. These highly felspathic gneisses recall the type so well developed in the east of Sutherland. Lenticles of garnetiferous amphibolite or hornblende-schist, traceable for no great distance, appear occasionally throughout the area occupied by these gneisses. Some of the pegmatites and granite veins traversing these gneisses, are foliated and share in the folding of the schists; other pegmatites, and these by far the larger number, are not deformed, and contain pink felspar (probably microcline), muscovite, and sometimes biotite. The fine-grained flaggy siliceous schists appear in the lower part of the Moniack Burn, on Torr Clunes and Rebeg, west and east of that stream. These are associated with a band of crystalline limestone, which has been wrought in the Rebeg and Clunes quarries, and with calcareous schists and calc-silicate hornfels, visible in these limestone quarries and in the Moniack Burn.

Two well marked faults have been detected in the crystalline schists; one trending E.N.E. in the upper part of Dochfour Burn, south of Blackfold, the other running N.N.E., along the course of Allt Mor (the upper part of the Moniack Burn). In both cases the streams follow the lines of fracture where the strata have been much brecciated.

Mr. Cunningham Craig.

Glen Urquhart.—The limestone and kyanite gneiss which were mentioned in last year's Summary of Progress have now been completely mapped, and it appears probable that they are of Lewisian age. The rocks are continued in a south-easterly direction into the one-inch map 73, and strike almost at right angles to the general strike of the Moine rocks, though near the junction the two sets of rock are parallel and have been intimately folded together.

The limestone and kyanite gneiss are folded along axes striking N.W. and are usually vertical or highly inclined. From the pitch of the folds it is possible to make out the following succession, beginning at the top :—

3. Felspathic banded gneisses with dark hornblendic lenticles.
2. Rusty micaceous gneiss with kyanite and occasionally graphite.
1. Limestone, rich in tremolite and malacolite, and at least from 30 to 60 feet thick. Base not seen.

The lowest rocks appear in the centre and the higher ones towards the sides of the area occupied by this series, and it seems clear that we are here dealing with a compound anticline rising from underneath the Moine rocks. The boundary between the supposed Lewisian rocks and the Moine rocks can only be approximately fixed, for the marginal bands in both are very similar in composition and state of crystallisation, but sections in several localities indicate that different beds in the lower series come in contact with the upper.

A large mass of foliated serpentine, representing an ultrabasic intrusive rock, occurs entirely within the lower series, but its age has not been determined. It does not appear to have been folded with the adjoining rocks.

The most general type in the Moine rocks is a finely banded felspathic quartz-biotite-schist or gneiss, with a considerable quantity of muscovite in some laminæ. About Lochan an Tairt and Creag Muigeil there are many thin bands of muscovite biotite gneiss, in which the muscovite occurs in large spangles lying at all angles, as well as in small flakes which follow the direction of schistosity. In the western part of the area the rocks are much contorted. Over a great part of the remaining area the angles of dip are generally gentle, and the folds are shallow and somewhat sharp, but it is possible that these are merely parts of a more complex system of flexure. That no great thickness of rocks is present seems probable from the constant repetition by folding of a sill of epidiorite. Near Loch Ness the beds become steeper, and on the shore they are vertical, perhaps in consequence of the proximity of the Loch Ness fault.

The outcrops of the sill of epidiorite which has just been referred to, are usually lenticular in consequence of folding, or of pinching out during folding, and rarely more than 5 yards broad, though thicker masses may be seen where the rock is folded on itself. In the neighbourhood of Corryfoyness the epidiorite becomes very conspicuous, and both the top and bottom may be seen. In the

ground to the southward only the lower margin is seen as a rule, while to the northward the upper margin is more frequently observed. It is possible that more than one sill is present in some places. Mr. Cunningham Craig.

Intrusions of older granite and pegmatite, which are of a white colour and generally in the form of thin sills less than 6 feet thick, are well represented in the Moine gneisses north of Abriachan. They show distinct cataclastic structures, and are often completely granulitised and gneissose. The foliation frequently runs parallel to the margins of the veins, but in certain cases it makes angles of 70° or 80° with them, so that it is clear it cannot be a protoclastic structure.

NEWER INTRUSIVE IGNEOUS ROCKS.

Corriefearn Area.—A great part of the area mapped in the N.E. corner of 1-inch sheet 93, near Corriefearn and Beinn nan Oighreagan, is composed of a fine to medium grained reddish biotite-granite, unfoliated, and with a considerable resemblance to the Cairngorm granite. Veins of more acid muscovite-pegmatite occur, both within and without the granite mass, the latter sometimes containing garnets and large crystals of tourmaline. The Moine schist within a furlong or more of the edge of the main mass is injected by numerous granitic strings, most of which are coarse in texture, but some are finer than the main mass. When weathered, the granite often shows a peculiar laminated structure, but the mineral constituents are not arranged parallel to it. Some small basic inclusions have been noticed. Messrs. Hinxman and Anderson.

The Abriachan Area.—This granite mass, though only 2 miles long and half a mile broad, makes a conspicuous landscape feature on the side of Loch Ness. The rock is of a red colour, of a fine or medium grain, and without any sign of rapid cooling at the margin. In composition it is more acid than the majority of newer granites, and contains abundant microcline, orthoclase, a little plagioclase, quartz and a small quantity of biotite. Mr. Cunningham Craig.

The margins, where distinct, are nearly vertical, and the dip of the contiguous Moine schists conforms to them to some extent. Veins of granite, frequently accompanied by pegmatite and aplite, emanate in tolerable abundance from the main mass, but seldom extend more than a quarter of a mile. The Moine gneisses, in contact with the granite, are indurated, but do not give any other clear evidence of contact alteration. The bands of epidiorite near the junction seem, however, to have undergone reconstruction and have been converted into fine-grained compact rocks, resembling a hornfels of sedimentary origin.

OLD RED SANDSTONE.

Strath Rannoch Area, Sheet 93.—Deposits of Old Red Sandstone and Conglomerate occur in Strath Rannoch, and up the valley of the Allt a' Choire Rainich, in such a way as to suggest that this Messrs. Clough and Anderson.

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valley was already in existence when they were formed. The materials of the conglomerate are composed mostly of Moine schist and foliated granite: enormous blocks of granite occur in the conglomerate near the junction line of the two formations.

The finer sediments include sandstone and mudstone; numerous bands of calcareous sandstone, and thin limestones occur along the course of the Allt a' Choire Rainich. A little to the north-east of the keeper's house at Strath Rannoch the sandstone shows a rough cleavage dipping N.W. about 70°.

In the conglomerate or arkose which is exposed in the burn running in a W.N.W. direction from near the N. side of Carn nan Con Ruadh, most of the pebbles are of siliceous schist and from one to two inches long, but smaller grains of quartz and felspar, which have no doubt been derived from the adjoining granite-gneiss form a large proportion of the finer material. Nearly half a mile W.N.W. of the Ordnance Station on Carn nan Con Ruadha, there is a coarse conglomerate containing boulders of augen-gneiss nine or ten feet long. It looks as if this bed came in below the finer beds in the lower part of the burn, but above those in the upper part.

r. Horne.

Dochfour Area, Inverness.—On Craig Leach, about a mile to the north of the mouth of Dochfour Burn, the southern limit of the tract of Old Red Sandstone west of the River Ness was mapped, where the strata consist of sandstones, shales, and pebbly grits with some bands of conglomerate. Close to the line of junction both the schists and the Old Red rocks are shattered and brecciated, pointing to the existence of a faulted boundary line between the two. At the head of the Bunchrew Burn, east of Blairnachenachrie, and again on the private road leading to Dochfour House, about 300 yards north of Dochfour Burn, the schists and Old Red breccia are seen close to each other. The fault at these localities is well defined, and it is probably a branch of the well-known fault along the Great Glen, as both have a similar downthrow.

PLEISTOCENE AND RECENT DEPOSITS.

r. Clough.

Diebidale and Carn an Liath-bhaid Area.—Most of the drift is of a loose sandy and bouldery character, and prominent morainic mounds and ridges are common. In some places, for instance near Lochan a' Chairn, there is an underlying more compact deposit which represents ground-moraine, and in the burn N.N.E. of Garbhairidh there are good sections of stiff grey boulder clay. Near the sides of the burn S. of Blar Garvary there are also various kames composed of well-rounded gravel and sand.

Glacial striæ occur on the granitic rocks near Carn Dubh, and in various places between Lochan a' Chairn and Carn an Liath-bhaid, and on the Moine schists E. of Glen Calvie. The general direction varies from 10° to 40° N. of E.

On the higher parts of Carn Chuinneag only a few boulders were noticed which could not have been derived from rocks *in situ* on the

hill; one, of siliceous schist, occurs at a height of about 2,550 feet, and there are also some of diorite at a height of more than 2,500 feet. Most of the steep sides, and a great part of the gentler slopes of the hill, are covered with scree-material and loose blocks of fine-grained granitic rocks, like those seen *in situ* near at hand. Mr. Clough

On Diebidale Ridge, Laac Ghorm and Dunach Liath there are also widespread stony deposits which seem to have been chiefly derived from the underlying siliceous schists, but on the west side of the ridge there are also many large boulders of augen-gneiss which must have been derived from the lower ground on the south-west.

There are no large areas of peat, except on the N. side of Dunach Liath and in the area drained by the Abhuinn a' Choire Bhuig, the hills being as a rule too steep to be favourable for the growth of moss. Stools of the Scotch fir (*Pinus sylvestris*) are common in the peat in most places, but in some parts of the Coire Bog they do not occur in the basal portion, about three feet thick, their place being here taken by remains of birch (*Betula alba*). In the same locality, seeds of the bog bean (*Menyanthus trifoliata*,—determined by Mr. Clement Reid) and remains of beetles, too fragmentary to be determinable, are abundant in certain layers, particularly in the basal portion.

Kildermorie Forest and Strath Rusdale Area.—The glacial striæ indicate that the direction of ice movement was chiefly somewhat south of east. Most of the drift is of a morainic character. Dr. Crampton.

District of Strath Rannoch and Loch nan Amhaichean.—One well-marked lateral moraine runs along the east side of the valley of Allt Coir a' Chundrain for about a mile. Below Strathrannoch House the morainic features on the east side of the valley generally strike nearly north and south, and they become less distinct and less boulder-strewn as they recede from the bottom. Messrs. Clough and Anderson.

Enormous boulders of augen-gneiss are scattered over the country with such a relation to the boundary of this rock as to show that the ice carrying them came from the west. Fragments of Old Red Sandstone are also found on the ridge between Strath Rannoch and Abhuinn Beinn nan Eun, and these too have probably been derived from the W. or W.N.W.

To the north-east of Loch nan Gobhlag there is a curious dry valley which has been blocked by drift just at the point where it is crossed by the valley of the present stream.

In the peat on a high river terrace on the E. side of Strath Rannoch, about 200 yards above the foot of Allt Leathad Carnach, remains of birch (*Betula alba*) are found near the base, but roots of the Scotch fir (*Pinus sylvestris*) replace these higher up.

Area between Strath Garve and Loch Glass.—The striæ observed in the Wyvis Forest show the general ice-movement, apart from local valley-glaciation, to have been in a direction varying between E. and S.E. Mr. Hinxman.

Ir. Hinxman.

A study of the disposition of the boulders of two easily recognable rocks,—Inchbae granite and Old Red Sandstone,—derived from the west, over this area, has brought out the important fact that while these erratics are abundant on the lower ground to the S. and E. of Ben Wyvis, pass through the valley of Loch Glass on the N., and occur plentifully up to a height of 2,400 feet on the tops of Carn Gorm and Little Wyvis, the western spurs of Ben Wyvis; not a single fragment of these rocks has been observed above the 2,300 feet level on that mountain itself.

Ben Wyvis forms an extensive elevated plateau of which an area of at least two square miles has a mean elevation of upwards of 2,500 feet. Such an extent of high level gathering ground implies the accumulation of a great amount of *nevé*, and the generation of a large ice-cap moving rapidly off the mountain.

It, therefore, seems reasonable to infer from the present distribution of these erratics, that, at the time when the western ice carried eastwards the boulders of Inchbae granite and of the Strath Rannoch Old Red Sandstone, Ben Wyvis was a centre of dispersion whose ice-flow was powerful enough to resist the invasion of the western ice, and to divert it to north and south through the valley now occupied by Loch Glass, and over the lower hills to the east of Strath Garve. The path of the southern ice stream along the south-eastern flanks of Wyvis is clearly indicated by the direction of the striæ, the trend of the moraines, and the disposition of the boulders of Inchbae granite and other known erratics.

Crossing over Little Wyvis, it poured through the pass between that hill and An Cabar, and swept eastwards round the foot of Meall na Speireig towards Allt nan Caorach. Here it was met by the northern ice stream that passed southwards through the valley of Loch Glass, and the two streams, converging, forced a lobe of ice for some distance up the glens of Allt nan Caorach and its tributary Allt Coire Measaich.

The level of the western ice on the eastern or lee side of Wyvis, as indicated on slopes where the latter valley glaciation can have had little or no effect, ranges from 1,200 to 1,600 feet; or about 800 feet lower than on the western side facing the ice-flow, where a well-marked lateral moraine, extending along the steep side of the mountain at a mean elevation of slightly above 2,000 feet, indicates the position of equilibrium between the Wyvis ice and that coming from the west.

No boulders of augen-gneiss or Old Red Sandstone have been observed on the lower N.W. slopes of Wyvis above the head of Loch Glass; or in the glen or on the col at the head of the pass south of An Cabar. The absence of such erratics from these localities when they might be expected to occur, is attributable to ice-action at a later period.

When by the shrinking of the western ice Wyvis was able to radiate its own system of independent glaciers, the blocks left behind by the earlier ice-streams were swept away by the large

glaciers pouring out of the corries to the south of Feachdach and east of An Cabar. Mr. Hinxman.

The phenomena described above may probably be referred to the confluent-glacier phase of the glacial period, when large convergent valley-glaciers, derived from a high ice-shed further to the west, flowed in an unbroken sheet over the lower hills of Central Ross-shire and Inverness-shire.

At the same time it should be pointed out that there is no evidence to show that even during the phase of maximum glaciation, ice from the west ever passed eastwards over the summit of Wyvis. Indeed it seems more probable that the mountain, even at that early period, occupied a position on the line of ice-shed, and that

Fig. 4.—*Map of Ben Wyvis.*

the boulders of Inchbae granite recorded by Mr. Gunn* as occurring far to the west on the shores of Loch Broom, were transported thither by an ice-movement initiated within a short distance of the east coast of Ross-shire, and earlier than that which subsequently carried eastwards boulders of the same rock, and scattered them far and wide over the Black Isle and the seaboard of Eastern Ross.

* Annual Report of the Geological Survey for 1896, p. 18.

Mr. Anderson. *Area between Corriefearn and Garbhairidh.*—Between the Eastern and Western Fearn Burns, much of the low ground is covered by moraine and sandy drift, and mounds of glacial sand are met with at one locality. Large erratics of augen-gneiss, of the same type as that *in situ* further west, are abundant. Glacial striæ trending north-east are found about three-quarters of a mile E. of Garbhairidh.

Dr. Horne. *Area between Dochfour and Moniack Burn, Inverness.*—Though there is everywhere abundant evidence of the intense glaciation of the region, striæ are not readily found in the area occupied by the coarse granulitic gneisses, save on the veins of quartz and the more quartzose pegmatites. Indeed nearly all the instances met with were furnished by such veins. From the striæ found at widely separated localities on the hilly plateau between Dochfour and Moniack Burn, the general direction of the ice movement seems to have varied from 25° to 35° N. of E. Ice-markings were observed on Cnoc na Gaoithe west of Dochfour House, on Cnoc na Moine north of Dochfour Burn, and on Mam Mor east of Moniack Burn, all at elevations above 1,000 feet and pointing in the direction just indicated. Similar evidence was obtained at lower levels.

In the valley of the Moniack Burn and on the north side of the Dochfour Burn, there is a thick deposit of stiff stony clay; excellent sections, some over 100 feet in depth, being laid open in the banks of the former stream. Thin intercalations of sand and clay appear in some of the sections of this deposit. The gently undulating contour to which this deposit gives rise is well developed on both sides of Allt Mor, which forms the upper part of Moniack Burn, and on the moorland that stretches eastwards by the head of Dochfour Burn.

On the northwest and north slopes of the hilly plateau north of Dochfour Burn, and especially in the district extending from Reelickwood by Aultnacardoch to Inchberry Hill and on Englishtown Muir, there are irregular mounds of drift differing in character from the typical boulder clay of the region. They are composed of sub-angular gravelly and sandy material with an admixture of clay; contorted stratification being of common occurrence. The mounds are evidently of morainic origin and later than the boulder clay, for in some sections, as on Englishtown Muir, they rest on the latter.

Mr. Cunningham Craig. *District of Glen Urquhart.*—The direction of the movement of the ice-sheet during the great glaciation is shown by the trend of numerous ice-worn hummocks of rock and intervening hollows, as well as by striated surfaces and the distribution of boulders, and it is clear that it was generally from south-west to north-east. Blocks of conglomerate derived from the Old Red Sandstone near Loch Glanaidh have been carried over Meall na h' Eilich and the higher ground between that hill and Abriachan, and many of them are now resting at elevations higher than their source.

Much of the lower ground is covered by boulder clay except on the side of Loch Ness, where a local glaciation has removed almost every trace of the deposit. In the great open hollow which stretches from Rivoulich to Inchbain and includes Abriachan, there has apparently been no local glaciation, and an almost unbroken sheet of boulder clay covers the ground, in some places to a depth of 50 feet. Mr. Cunningham Craig.

A good example of a kame is seen half a mile W.N.W. of Tor Mor. It occurs close to the margin of the drift and has been traced in a north-easterly direction for 250 yards.

A narrow terrace, composed of well stratified sand and gravel, and never more than 100 yards broad, is found near Brachla, on the western shore of Loch Ness. The height above the loch is from 20 to 30 feet. The uppermost limit does not reach the 100-feet contour, but it is possible that the terrace may be a relic of the 100-feet raised beach. Another, and perhaps more probable, theory is, that it was formed at a time when the surface of the loch stood at a higher level than now.

PHYSICAL AND ECONOMIC FEATURES.

The largest part of the area (1-inch map, No. 93), surveyed this year is of a wild hilly character and used as deer forest. The ground on the N.E. side of Abhuinn Shalachie, Lochan a' Chairn and Creachan an Fhiodha is generally less elevated than the rest, and forms sheep and grouse ground. For these reasons the country is thinly populated. Messrs. Clough, Hinxman, Crampton, and Anderson.

Ben Wyvis is composed of the rocks of the Moine series, and forms a high mountain plateau, with deep glens and corries on the eastern side, which reaches the height of 3,429 feet and dominates the surrounding country for many miles. With the exception of Carn Chuinneag, the areas occupied by the older granite rocks are generally smoother, and more peat covered, and sometimes rather lower, than the adjoining schistose areas.

Glen Diebidale, on the N.W. side of the Carn Chuinneag ridge, is much deeper than the glens on the S.E. side and affords excellent sections. Near the head of the glen the granitic and the basic rocks are tolerably distinct in the landscape, the former being often heather-covered, while the latter have more often given rise to green grassy slopes.

The newer granite of Fearn is often deeply weathered into a coarse sandy material, and has given rise to unusually smooth features in the landscape.

The strings containing magnetite and cassiterite, which occur in the granitic mass near old Diebidale Lodge, are described in the Appendix. Until further examination is made in the Field, it is impossible to say whether they are likely to offer a profitable opening for tin mining or not.

Some pieces of iron slag have been found at the side of Abhuinn Shalachie, about half a mile slightly S. of E. of the top of Cnoc na Tuppat, and there has probably been an old bloomery here, but no indications of mining are known in the vicinity.

In the small burn about a mile W.S.W. of Cnoc na Tuppat there is a crushed intrusive rock, and a vein containing quartz, some ferriferous carbonate and some small specks of Galena.

Mr. Cunningham Craig.

District of Glen Urquhart.—The area surveyed is not included in Deer Forest, and though of a hilly character and with a considerable extent of grouse moor, it is occupied by a considerable population. It is diversified and sheltered by extensive well grown woods, and houses and fields creep up the hillsides beyond the 900 feet contour. The climate is not very wet, and the Caledonian canal affords good facilities for communicating with Inverness and the outside world.

The Abriachan granite has formerly been quarried for building stone, for which it is well suited, but only for local purposes. It is a handsome stone, uniform in character and would take a good polish, but owing to the number of joints it is impossible to obtain large slabs, such as can be supplied from the Aberdeenshire granite quarries. The quarries that were formerly worked are not well situated for facilities of transport.

The limestone has been quarried extensively and burnt into lime in several old kilns, one of which is still occasionally used. Only the purest bands, which are free from tremolite, malacolite, etc., can be profitably burnt, and such bands are not thick, and are difficult to follow in consequence of the constant folding.

3. District of the Small Isles.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. A. Harker, M.A., F.R.S., Geologist.

TORRIDONIAN.

Isle of Rum.

Mr. Harker.

In completing the survey of the Isle of Rum, Mr. Harker found that the Torridonian strata occupy a somewhat larger area than has hitherto been recognised. In their relatively undisturbed position they form a strip of some width extending from the large continuous tract in the north, along the eastern and southern coasts, nearly to Papadil. In addition, overthrust rocks of the same group extend high up the flanks of the southern mountains Sgurr nan Gillean and Ashval. Here they are highly disturbed, in great part brecciated, and metamorphosed by the Tertiary plutonic intrusions which invade them.

JURASSIC.

Isle of Muck.

In surveying the Isle of Muck, Mr. Harker mapped the Oolitic strata which occur at Camas Mor, on that island, occupying a considerable stretch below the high water mark. The thickness shown is greater than has hitherto been estimated, and the succession is as follows, in descending order :— Mr. Harker.

	Ft.
(*c*) Cement-stone group (hydraulic limestones, shales, etc., with a Paludina-bed)	20
(*b*) Ostrea hebridica group (oyster-beds alternating with lead-coloured shales)	65
(*a*) Great Estuarine Sandstone, upper portion	30
	115

This sequence is exhibited in the western half of the bay. On the eastern side, part of the same strata are seen in a highly disturbed and often brecciated state, and in addition metamorphosed by an intrusion of gabbro.

TERTIARY IGNEOUS ROCKS.

Rum.

Excepting the Torridonian strata already mentioned, the southern and western parts of Rum consist of plutonic rocks, the ultrabasic group especially being in great force. It consists of three sub-groups, intruded in order, as follows :- (*a*) Peridotite-Allivalite sub-group : varieties ranging from pure olivine-rock to pure anorthite-rock, more and less felspathic types often alternating in parallel sheets ; varieties rich in pyroxenes not common, but a pure enstatite rock occurs exceptionally. (*b*) Harrisite sub-group : the characteristic type is an enstatite-anorthite-rock. (*c*) Eucrite sub-group : olivine-pyroxene-anorthite-rocks, both hypersthene and augite being usually present. Under this last head are to be included the rocks termed gabbros in last year's report, their real affinities being rather with the ultrabasic than with the basic group. True gabbros (with labradorite) do not occur to any great extent in this island.

The granite group, besides making a considerable spread in the west, recurs about Sgurr nan Gillean and Ashval, being there in very intimate association with the eucrites. Certain well banded gneisses were mentioned in the last report as occurring in isolated small masses. They are found in much greater force about the southern mountain, the largest area occurring to the west of the peaks named ; and here the genesis of these gneissic rocks can be studied in every stage, amply confirming the conclusions formerly reached from less complete data. A large amount of eucrite has

Mr. Harker.

become enveloped and partly incorporated in a granite magma, the whole being then drawn out into bands while still effectively fluid.

In the west of Rum, forming the hills Creag nan Stairdean and Fionn-chro, occurs the greatest development of mugearite yet observed. This rock-type was first fully described and named in Skye, but had been remarked at an earlier date (under the name porphyrite) by Sir Archibald Geikie in Eigg. It is also found at one or two places in Canna. In Rum it forms a group of sheets with a total thickness of about 500 feet.

Eigg.

The Jurassic strata prominent along the northerly coasts of Eigg sink below sea level near Kildonan on the east side, and near Laig on the west; so that the southern half of the island is built wholly of Tertiary igneous rocks. These are seen as alternations of amygdaloidal basalt lavas with dolerite sills, the latter being on the whole predominant, and also, in virtue of their superior durability, forming the conspicuous features. The only important exception is made by the highest ground in the island, the bold curved ridge or narrow plateau which culminates in the Sgurr. This is made by the well known porphyritic pitchstone.

In addition to the usual N.W. and S.E. basic dykes, which are rather frequent in some parts of the island, there are two or three felsitic intrusions, and at Rudh an Tancaird on the southern coast occur two dykes of a very beautiful pitchstone. In some places, and especially near Kildonan, are found irregular sheet-formed intrusions of basalt with glassy selvages.

Castle Island is of the same constitution as the neighbouring part of Eigg.

Muck.

The Isle of Muck, again, with the exception of the Jurassic strata at Camas Mor, consists essentially of alternating basalt lavas and dolerite sills. Volcanic agglomerates, enclosing blocks of scoriaceous basalt several inches in diameter, occur at or near the base of the group at two places on the coast.

An interesting point is the occurrence of gabbro, to be correlated with the better known intrusions in Skye and Mull. It forms a bold range of cliffs on the east side of Camas Mor, and extends, with an interruption, nearly to Gallanach farm house, having the general habit of a great dyke.

Muck is pre-eminent among all the islands for the extraordinary number of basic dykes which intersect it. They have a very general parellelism in direction varying from N.N.W. to N.W.

Horse Island differs in no way from the neighbouring part of Muck.

Canna and Sandy.

In these islands the monotonous alternation of basaltic lavas and dolerite sills is varied to the east by the interpolation of a considerable thickness of volcanic agglomerates and conglomerates. These are well displayed on the shores of the harbour or sound between the two islands and in the bold cliffs at the east end of Canna, but die out rather rapidly, their place being taken by basalt lavas on the same horizon. The fragments in the accumulations are mostly rounded, and towards the top include travelled rocks as well as the prevalent basalt, while fine tuffs are interstratified at various horizons, and often contain plant remains. These are found occasionally, even in a very coarse accumulation, including blocks several feet in diameter, at the base of the formation. The dolerite sills are much less frequent in these fragmental accumulations than in the lavas, and they sometimes show curious irregularities of behaviour. Mr. Harker.

Canna and Sandy are remarkable among the Inner Hebrides for their small number of basic dykes, elsewhere so numerous.

4. Western Midlothian and West Lothian District.

Dr. B. N. Peach, F.R.S., District Geologist.

Mr. L. W. Hinxman, B.A.
Mr. J. S. Grant Wilson
Mr. E. H. Cunningham Craig, B.A.
Dr. C. B. Crampton
} Geologists.

Carboniferous.

The most important result of the revision of the Carboniferous Rocks in the western edge of the Midlothian Coalfield has been the modification of the boundary lines of the areas occupied by the Roslin Sandstone (Millstone Grit). In the last edition of Sheet 32 of the one-inch map, this sub-division is represented as occupying two basins, separated from each other by a belt of the Carboniferous Limestone Series, nearly three miles in breadth; the Coal-measures being confined to the basin north of Penicuik. The evidence recently obtained shows that a continuous belt of strata, overlying the No. 6 limestone, which is regarded as the base of the Roslin Sandstone group, stretches between the two areas; and further, that at one place within this belt, immediately south of Penicuik, a small outlier of Coal Measures occurs. The plants collected from these rocks by Mr. Tait, in a stream flowing into the North Esk south of Glencorse Barracks, confirm these conclusions, as they belong partly to the lower and partly to the upper divisions of the Carboniferous system as determined by Mr. Kidston. Mr. Hinxman and Mr. Wilson

In the part of the district between Auchencorth and Penicuik the simple basin-shaped arrangement of the strata which exists to the north gives place to a succession of synclinal and anticlinal folds,

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some being gentle, some steep sided, while others towards the south-west, especially near the western boundary of the field, are isoclinal with the crests of the anticlines bent over towards the east. This arrangement involves considerable modification of the lines of outcrop of the different coals and limestones. The effect of the folding on the outcrops of Nos. 4 and 5 limestones and the intermediate coals is well seen along the course of the Esk near Brunston, and in the Harden Burn at Cornton.

Further to the west, and near the Pentland Fault, the folding is more pronounced, and in Habbies Howe, one of the lowest seams of the Edge Coals, forms a sharp isoclinal anticline. The inversion of the beds at that locality has already been observed and recorded.*

Similar rapid folding at high angles is also seen along the River Esk immediately above Glencorse and in the Straiton Oil Shale workings, as recorded on the present map. The little outlier of the North Greens Coal west of Gilmerton rests in a syncline; the western limb in places being folded over beyond the vertical. The eastern limb of the anticline cutting off this syncline of coal from the main outcrop on the edge of the Midlothian basin is also much the steeper one, and nearly approaches the vertical. There is thus a belt of considerable width of these rapidly folded strata east of the Pentland Fault, which is suggestive of the idea that the fault is the result of an upthrust from the west and that the hade of the fault may be towards the west.

ilson.

The recent revision has further shown that the limestone outcrops between Glencorse and Penicuik, which are represented on the map as underlying the Edge Coals, are really those of the Upper Limestones. Hence the outcrops of the Edge Coals and the lower limestones are shifted further west, and likewise the limits of the Edge Coals in that region.

Mr. Wilson has measured the Carboniferous Limestone and Calciferous Sandstone strata, exposed in the Bilston Burn near Loanhead, which, together with information obtained from the mining operations in the neighbourhood, has enabled him to construct a vertical section from the top of the Carboniferous Limestone series to a depth of 200 fathoms below the Burdiehouse Limestone that underlies the workable oil shales in this region. New information has been obtained regarding the outcrops of limestones and Edge Coal seams exposed in the railway sections at Loanhead and Gilmerton.

Mr. Wilson also finds that some of the oil shale bands have been opened in the Burdiehouse Burn about half a mile to the west of Gilmerton, to the north of the outcrops shown on the present map. They also reappear to the west of that outcrop, in the line of the Gilmerton syncline already referred to. This has been proved by bores put down near Kaims, while the outcrop of the Dunnet shale

* Memoirs of the Geological Survey of Great Britain: Sheet 32 (Scotland), p. 80.

has been laid bare near Broomhill Cottage, about half a mile west of Straiton, and that of the Broxburn shale at Broomhill, a little further to the north. In both cases the shales were seen to dip gently towards the N.N.W., showing that these outcrops are on the east side of the syncline. The medicinal qualities of St. Catherine's Well, about a mile west of Gilmerton, which is on the line of the Pentland fault, are perhaps largely due to the presence of petroleum, which is observable on the surface of the water. At Straiton, a quarry opened in a sandstone on the horizon of the Binney Sandstone had to be abandoned owing to the rock being impregnated with, and discoloured by, crude oil. Mr. Wilson.

The revision of the oil shale field west of Edinburgh has resulted only in minor alterations of some of the shale outcrops and lines of fault, as shown on the existing sheets. One of the more important changes occurs in the Breich shale field, where an outcrop, shown as that of the "Fells Shale" has been proved in mining operations to be that of the Dunnet shale, which occupies a much lower horizon. An outcrop of oil shale, 12 feet thick, has been traced for some distance to the west of Dalmahoy, but its actual horizon is as yet unknown. It shows, however, that there is still an unexploited shale field in this part of the area.

The opinion expressed in the Summary of Progress for 1902, p. 116, that the so called "Dunnet Shale" of the Philipston district is in reality the "Grey Shale," has been confirmed. A diamond drill bore has been sunk through this band and is at present cutting the Binney sandstone, which overlies the Dunnet shale.

In the part of the area lying between the oil shale fields and the Pentland Hills, Mr. Wilson has been able to trace several zones and belts of rock more completely than has hitherto been done; for instance, the volcanic zone on the horizon of that of Arthur's Seat and also the underlying Cement-stone group of Ballagan type. Near the Pentland Hills the beds become conglomeratic; a considerable proportion of the pebbles being composed of radiolarian chert.

Dr. Crampton revised the outcrops of the Calciferous Sandstone rocks immediately north and west of the City of Edinburgh, with the object of defining the limits of the Craigleith Sandstone and the overlying Wardie shales. He traced the outcrop of the Wardie shales round the Craigleith anticline and examined the same rocks where they reappear in the cuttings of the suburban railway near Craiglockhart Station. The section of the Wardie Shales in the water of Leith near Colinton was revised; special attention being paid to their marine fossil zones. Dr. Crampton is of opinion that the Hailes Sandstones lie in a syncline of the Wardie shales, and are the highest beds in that area, thus confirming the opinion of the late Mr. John Henderson. Dr. Crampton.

OLD RED SANDSTONE.

The importance of the cornstone horizon, as indicating rocks of Upper Old Red Sandstone age, is now generally recognised

That this zone belongs rather to the Upper Old Red Sandstone than to the Carboniferous formation is supported by the fact that it is interleaved in sandstones yielding scales of *Holoptychius nobilissimus* near Cockburnspath, Berwickshire.

IGNEOUS ROCKS.

The further re-examination of the Lower Old Red Sandstone rocks of the Pentland Hills in the main confirm the volcanic succession laid down by Sir Archibald Geikie, although the new work involves the alteration of some of the lines shown on the existing maps.

A large suite of rock chips, illustrative of the igneous rocks of the Pentland Hills, and more especially of the intrusive bosses, dykes, and sheets traversing the Carboniferous strata, has been gathered for microscopic examination.

PEAT.

In addition to the mapping of the solid rocks in the area west of Edinburgh and in West Lothian, Mr. Wilson traced the boundaries of several workable peat mosses in that region. Mr. Hinxman also defined more accurately the workable parts of the Auchencorth moss on the east side of the Pentland Hills.

5.—Eastern Midlothian and Haddington-shire District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. G. Barrow.
Mr. W. Gibson, B.Sc.
Mr. C. B. Crampton, M.B., C.M. } Geologists.
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.

The area revised last season includes, among other rocks, nearly all the true Coal Measures in Mid-Lothian, as well as the coals in the Carboniferous Limestone Series (Edge Coals) of the Mid-Lothian Basin.

Mr. Gibson, who was temporarily transferred from the English branch of the Survey for one month, revised the important mining district of Niddry, and rendered valuable assistance in many ways.

Many mining plans have been examined, and copies of the journals of many bores have been procured. The mining plans which were in existence at the time of the original survey have not been examined, except in a few cases where it was specially desired to acquire further information. Special thanks are due to the mining managers, engineers and surveyors who have kindly assisted.

In the northern portion of the coalfield a marked contrast exists between the inclination of the strata on the west and east sides of the basin. Those on the west dip at high angles, from 50° to 90°, or they are even reversed in certain places: indeed in the workings of the Niddry Collieries they retain a high angle of dip down to 2,000 feet below the surface, after which they rapidly flatten out till at a point about a mile east-south-east of Niddry House the inclination is only three degrees. On the east side of the basin the inclination does not usually exceed 25° or 30°. It seems probable, therefore, that the syncline has been developed under the influence of considerable earth pressure acting from a westerly direction. Dr. Crampton.

CALCIFEROUS SANDSTONE SERIES.

Garlton Hill and North Berwick Area.—Early last season Mr. Barrow continued the re-examination of the volcanic rocks of this region. At the base of the olivine-bearing rocks, he finds (1) a markedly basic rock, enclosing granules of olivine in a ground mass characteristic of basic olivine dolerite. Higher up, the excess of basic material, as shown by the large porphyritic augites, for the most part disappears, and we have (2) an olivine dolerite with more felspar. Still higher up is (3) an olivine dolerite with so many large crystals of basic felspar that it may conveniently be called the "felspar-rock." The evidence suggests that in at least one part of the area there was a still less basic top to the series. It appears that the mass or masses of olivine bearing material were either poured forth a little below the surface, or, what is more probable, that they filled a sunk area and formed a vast mass of molten material like that of Kilauea. Mr. Barrow

Close to the large quarry on the north side of the road about a mile west of East Linton, a rock of the type of the Congleton volcanic sheet*, which has often an almost spongy top but appears to show evidence of intrusion in places, cuts across the junction of the felspar rock and the underlying mass, and is evidently intrusive. The evidence suggests that the rocks of the Congleton type which were first poured forth, consolidated as andesites, in which the felspar microlites were nearly all plagioclase, but that, as the extrusion proceeded, the outpourings became more acid and finally gave rise to sanidine microlites.

As already stated, the Congleton type of rock often underlies the felspar-rock; immediately above the latter, however, is a sheet of fine trachyte, weathering at times into oval masses like the Congleton rock, but easily distinguished from it by the aid of the microscope. Excepting in one small obscure area at the foot of the Garlton Hills, the felspar rock and this trachyte retain their relative positions all the way from the coast west of North Berwick, to

* Summary of Progress for 1902, p. 124.

r. Barrow. the foot of Traprain Law. This trachyte is singularly uniform in composition and is almost certainly a sill which has been intruded not far below the surface. The other trachytes in the district, those with large porphyritic crystals, on the other hand, are, as a rule, of a much more limited extent and of more variable composition. Some at least of these were probably extruded at the surface, and individual sheets are sometimes separated by local masses of agglomerate. An example of rapid variation in one of them is well seen in the Bangley Head quarry, on the south-west face of the Garlton Hills. At the east end, the rock contains many large crystals of sanidine felspar, some as much as two inches long, and is probably one of the finest examples of a porphyritic sanidine tracyhte in the British Isles, but at the west end these large crystals have almost entirely disappeared.

It is probable that, as suggested last year, portions of the volcanic series projected above water in several places for a considerable period during the deposition of the Calciferous Sandstone series, and were denuded before the formation of the overlying sediments. To the west of North Berwick there is, close to the plug of olivine dolerite at Yellow Plantation and also on the scars, a conglomerate which is composed almost exclusively of the neighbouring felspar rock, and the accompanying trachyte, and must therefore indicate a local unconformity.

A greater break, however, perhaps occurs on the ground south-west of the outcrop of the volcanic rocks. In this locality one of a series of bores, the journal of which was obtained by Dr. Crampton, who helped to investigate the evidence on the field, was sunk entirely in trachyte. Many years ago an earlier boring, which passed through a limestone of the Aberlady group, was put down near the site of the foregoing. By the aid of an adjacent well section and these two borings, the outcrops under the drift were plotted, and it was found that the outcrop of the limestone was not broken by any large fault, and that a mass of trachyte must project almost to the base of the limestone, into the sedimentary rocks overlying the trachyte.

r. Bailey. *Haddington District.*—Considerable evidence has accumulated to suggest that the fault already mapped from Dunbar to Whitelaw Hill, north-west of Garvald, continues nearly parallel to the Silurian boundary fault, much farther to the south-west, as far even as the western edge of one-inch Sheet 33. The line of fault is marked in places by signs of disturbance, and appears also to divide the Calciferous Sandstone district into two parts; a N.W. part in which rocks are seldom seen which lie much below the Carboniferous Limestone series, and a S.E. part in which all the rocks are on a much lower horizon. In the latter part, exposures of volcanic ash have been observed in several places, and this year beds of the Cement-stone group have been found in the Humbie Water dipping under a thin bed of volcanic agglomerate. This agglomerate is

probably, therefore, on the same horizon as the Lower Carboniferous volcanic rocks of the Garlton Hills, and it is reasonable to assign this horizon to the other outcrops of ash.

CARBONIFEROUS LIMESTONE SERIES.

Lower Limestone Group.

East side of the Midlothian Basin.—A good limestone containing crinoids and slightly over 5 feet thick, and underlain by 19 inches of calcareous shale, was cut in the Lady Victoria shaft, Newbattle. It lies 25 feet above a big limestone, about 51 feet thick, the latter being probably the same as that which comes to the surface in the anticline near Hillhead and the Roman Camp. It is doubtful whether the five feet limestone is ever seen at the surface in this district, but it is probably represented in the railway cutting near Crossgatehall, north-west of Dalkeith. Messrs. Clough, Crampton and Anderson.

In the above mentioned railway cutting there is, about 90 yards east of the bridge, a nearly vertical N.N.E. fault, on the west side of which we see many coals belonging to the Edge Coal Group, while on the east side comes a set of sandstones, shales, thin limestones, and coals. A little below one of the limestones is a parrot shale, 8 feet thick. It appears necessary to suppose that all the beds seen on the east of the fault are higher in stratigraphical position than the thick limestone which has been quarried a little south of the cutting, but lower than the Parrot Coal which lies near the base of the Edge Coals. If this be the case, the beds must undergo a great change in the interval, of about four miles, which intervenes between Crossgatehall and the Tyne Water, near Vogrie; for in the latter locality the strata between the Parrot coal and the thick limestone are about 100 feet thick, while at Crossgatehall the beds seen east of the big fault are more than 300 feet thick.

The boundaries of the limestone outliers which crop out along the arch of the anticline between the Roman Camp Hill and Crossgatehall have been considerably altered. It is now supposed that the sandstone in the wood at Hillhead is a bed above the limestone No. 3, and that it forms part of a little outlier, not an inlier. In one of the quarries in the west part of the wood the limestone is affected by a sharp fold and dips steeply east for a little space, and it is believed there may be a parallel fold of the same kind a little farther east. The limestone is so thick that it hardly seems as if the beds below it could come to the surface in this locality. Dr. Crampton.

The limestone No. 2 of Tyne Water is seen in various places between Cousland and Mayfield. It is at least 50 feet thick, and consists in the upper part chiefly of soft "calmy" bands, which are separated from the lower heavy limestone by a dark ink-coloured band of impure limestone. The heavy basal bed, about 15 feet thick, is mined extensively throughout the district, and is known as the "Mine" limestone. A little above the limestone there is a thin coal, which is also known in Tyne Water.

The rocks underlying this limestone are only known to come to the surface in this district at one locality which is a short distance from D'Arcy Farm, where a thin coal and more than 100 feet of other strata were pierced in a bore which started just below the limestone.

Temple Area.—The limestone in the bed of the river near Yorkston is probably the top of the limestone quarried at Esperton, and of limestone No. 3 of Tyne Water. Some distance above it there is a thin calcareous band, becoming in places a tolerably good limestone with fossils, which is believed to represent the limestone which was struck at the bottom of No. 17 bore of the Arniston Coal Company, where it had a coal with "parrot" close above it. This thin limestone is well seen in the South Esk above Temple, and also as an inlier in the bed of the river between Temple and the junction of the South Esk with Redside Burn.

Gilmerton District.—Limestone No. 1 is 70 feet thick, and limestone No. 2 is 24 feet. The thicknesses given in the Geological Survey Memoir were perhaps merely intended to refer to the portions which were considered best for lime burning.

Edge Coal Group.

Area between Gorebridge and Crossgatehall.—In the Lady Victoria shaft, the strata embracing the Edge Coal Group, between No. 4 limestone and the thin limestone which is below the Parrot seam, and which may be considered as the top of the Lower Limestones, are about 646 feet thick,* and they include seventeen coals, which have a thickness of 2 feet or more, as well as many thinner seams. Most of the seams are not, however, considered profitable to work at present, at great depths, and in the Victoria pit the only ones which are now being mined are the Parrot seam and the Bryans Splint.

The Parrot seam,—the lowest in the group,—is not, on an average, more than 3 feet thick, but it is profitable to follow it to great depths as it contains, near the middle, a thin seam of parrot which is a very good gas producer, and the upper portion, called the jewel coal, makes also an excellent house coal. At Arniston and Newbattle the Parrot varies between 6 and 9 inches in thickness, but farther north it becomes thinner and in the old Cowden pit is said to be only an inch thick. Above the jewel portion of the coal there are 2 or 3 inches of dark, finely laminated shale which contain abundant remains of *Lingula*, overlaid by a band of ironstone, called the "bane," which is about 4 inches thick and is said to be very persistent. The ironstone makes a good roof to the coal workings, and contains in places abundant remains of *Carbonia* (?). The *lingula* shale was found in the Lady Victoria pit, the Emily pit, and in an old level at Common (Gorebridge), and, judging from the waste heaps at the tops of many of the old abandoned pits, it must be of general occurrence in the Newbattle and Gorebridge district.

*In the thickness given here, and in many of the thicknesses subsequently a deduction has been made as an allowance for the dip.

A little above the highest limestone in the burn north of Vogrie House there is a coal which has 1 or 2 inches of *lingula* shale above it, and over this again an ironstone band 2 or 3 inches thick. There can be little doubt that this coal represents the Parrot coal, though whether it contains any Parrot in this locality is doubtful, no complete section of it being exposed. Mr. Clough

In some parts of the "Carrington Dook" there are, in the shale six or eight inches above the "bane," fossil shell remains, which Dr. W. Hind has determined as *Naiadites carinata* and *Naiadites modiolaris*. The geological horizon is believed to be the lowest at which these shells have yet been found. In England they are said to characterise the Lower and Middle Coal Measures.

A seam of *lingula* shale occurs in some places just above the Kailblades or Rough Coal, between 100 and 140 feet above the Parrot Coal. It was mentioned as occurring at Bryans by Mr. David Milne Home* so long ago as 1839, and is at present well exposed at Common (Gorebridge), where it is 2 or 3 inches thick and overlain by about 15 inches of shale with ironstone nodules, but in the Lady Victoria pit it was not found in the places which were searched.

In both the Emily and Lady Victoria pits the Kailblades coal is much mixed with partings of clay and thin-bedded sandstone, frequently full of vertical rootlets. The two coals, about 8 feet apart, which are exposed in the old quarry at the north end of the wood between Lawfield and Langlaw probably represent two portions of the Kailblades coal with a thicker parting than usual. On the south side of the quarry there must be two folds, each with a nearly east and west axial plane. A sandstone which occurs a little above the Kailblades coal, and which in the Masterton quarry is about 40 feet thick, contains in parts a good many grains of quartz as large as a pea, being much coarser in grain than most of the sandstones which occur in this district in the Edge Coal Group. In the Crossgatehall railway cutting there is, however, an equally coarse sandstone on a much higher position in the group.

The Bryans Splint Coal, about 60 feet above the Kailblades seam, is sometimes six or seven feet thick and is an excellent house coal. Parts of it are, as the name implies, of hard splint coal which can be got out in large blocks. Above it there are often 12 or 13 feet of shale with small nodules of ironstone and thin, even courses of sandstone.

The coal, which is called the Coronation, in the Lady Victoria shaft rather more than 136 feet above the Bryans Splint seam, is pyritous and said to be liable to spontaneous combustion. About 23 feet below this coal, a thin limestone, rather more than two feet thick, was cut in sinking the Lady Victoria shaft. An examinatioa was made for this band in the "Newbattle incline" and a calcareous sandstone, two or three feet thick, and with abundant remains

* "Memoir on the Mid Lothian and East Lothian Coalfields," p. 38.

Ir. Clough. of *Productus semireticulatus*, was found between 20 and 30 feet below the coal. This calcareous horizon is rather more than 300 feet below No. 4 limestone, and not far from the middle of the Edge Coal Group. It is not shown in the shaft section of the Emily pit, Arniston.

In the Lady Victoria shaft section, limestone bands, about 26 inches thick, were met with about 41 feet below the Diamond Coal. The beds on this horizon are not now visible in any part of the colliery, nor in any surface exposure in the neighbourhood. At Crossgatehall, four miles distant, no corresponding calcareous band was detected.

The Great Seam is six or seven feet thick at Arniston, Newbattle, and near Smeaton Shaw. At Arniston it is not of very good quality and is classed as a steam coal. In all these places it contains a band of Parrot a little above the base, but this band is not of such excellent quality as that from the Parrot Coal, and at Arniston, where it is three inches thick, it is mined separately. The Great Seam is exposed obscurely near the western end of the Crossgatehall railway cutting, and here it contains, as usual, a band of Parrot near the base: above the coal comes a rather massive sandstone about 30 feet thick, which is well represented also at Arniston, Newbattle, and Cowden.

There are not many good surface exposures of the beds under review. The best are those at Common (Gorebridge), in old quarries near East Houses, Lawfield, and Cowden, and in the railway cutting at Crossgatehall.

The most important fault which has been proved in the underground workings in this district since the time of the original survey is the Easthouses and Cockpen fault, which passes near Easthouses and has a large downthrow to the north-west, amounting in the Parrot Coal near Bryans to 280 feet.

Mr Gibson. *Niddry.*—The Great Seam is about seven feet thick and contains near the top a band of "parrot" 27 inches thick which is of very good quality.

In the Carlton "cross-cut" of the Niddrie Collieries there is a black finely laminated shale, about a foot thick, which contains a good many remains of *Lingula*. This shale is about 110 feet above the Peacocktail Coal and 246 feet below the Great Seam. It lies about half-way between the Stinkie and the Black Chapel, and seems, therefore, to be on a higher horizon than the shale which Dr. Traquair* records as containing *Lingula* at Loanhead, and which overlies the Brown's coal.

The Carlton and other Lower seams are not now visible in this colliery, but it is stated by Dr. Traquair (*op. cit.*) that a somewhat similar shale also exists in this western side of the basin near the

* "On the Distribution of Fossil Fish Remains in the Carboniferous Rocks of the Edinburgh District." *Trans. Roy. Soc., Edin.*, vol. xi., part iii., p. 694.

horizon of the North Coal, the lowest of the Edge Coals. It is probable that this lower shale is on the horizon of the similar shale, which occurs above the Parrot Coal of Newbattle and Arniston. (See p. 102.) Mr. Gibson.

Search was made to see if any calcareous beds exist in the same cross-cut which might correspond to those known to occur on the eastern side of the basin at Newbattle, below the Diamond Coal and the Coronation, but none were found.

District of Prestongrange and Carberry.—A coal pit has been sunk at Carberry since the time of the original survey, while two have been sunk quite recently at Prestonpans (Northfield Colliery and Bankton). The Preston Links Colliery, which has been for some time abandoned, is being restarted. Here the dolerite dyke, which formed the northern limit of the old workings, has been pierced, and coal has been found to the north, under the Firth of Forth. Coal is also worked to a considerable extent under the sea from Prestongrange Colliery, and it seems as if under-sea workings may have a considerable development in future in this district. Mr. Anderson.

From information obtained through extended workings at Wallyford, and from the Carberry pit, it has been found possible to indicate on the map the outcrops of two seams, the Four-Feet seam and the Five-Feet seam, below the two indicated on the published map. The fault running S.E. from Monktonhall has been found to continue past Carberry Tower, and to shift the outcrops of these seams considerably. Another fault, with a downthrow to the north, diverges from this one near Carberry Mains. Near Wallyford a dyke of white trap, 10 feet across, has been cut through in the colliery workings, and may be continuous with the dyke which occurs at Brunstane, on the other side of the Mid Lothian basin.

At Prestongrange the most important seams are the Great Seam and the Jewel. The latter appears to correspond with the Five-Feet seam of Wallyford. An intermediate seam, the Clay Seam, which is worked chiefly for the sake of a layer of fireclay underneath it, may be the same as the Wallyford Jewel. At this colliery the dolerite dyke, already referred to as having been cut through at Preston Links, is being approached about half a mile out to sea. This determines the course of this dyke about two miles further west than it was previously known. The lowest seam seen in this colliery is called No. 1 Diamond, and is not worked, being only about 29 inches thick, and with a four inch parting of shale near the middle. It seems not unlikely that it may correspond to the Kailblades Coal of Newbattle and Arniston, as there is a two-inch shale above it which is full of remains of *Lingula*. Above this comes a band of shale four-inches thick, and then an ironstone band, about three-inches thick.

Further east, at Prestonpans, the outcrop of the Great Seam has been traced for some distance along the shore, where it is cut by a number of small faults, mostly with downthrow to the north. At Northfield and Preston Links collieries the principal coal-seams

Mr. Anderson. are the same as at Prestongrange, namely, the Great Seam, some intermediate seams, and the Jewel. At Bankton the principal coal seams worked are the Bankton Splint (which probably corresponds to the Wallyford Jewel) and the Jewel of Prestongange. Above the latter coal, both here and at Northfield Colliery, Mr. Tait has found a shaley bed containing Lamellibranch shells, of which the following is a list:—Bankton Pit—*Naiadites modiolaris* (common), *Anthracomya Williamsoni, Carbonicola aquilina.* North field Pit—*Naiadites modiolaris* (common), *Naiadites carinata.*

Mr. Bailey. *Port Seton.*—The coals of the East Lothian basin have never been followed out to sea, for the Government refused permission when the project was suggested nearly a century ago. This information has been supplied by Messrs. Williamson, Miller, and Robertson, and according to their records the Great Seam in the small pits east of Port Seton was found to be between five and six feet thick. Modern improvements in pumping appliances may perhaps render the under-sea working of this coal practicable at an early date.

There is a common misconception among mining men who know this district, despite the mapping of the Geological Survey, that the Port Seton basin is of a complicated character and that one of the big coals seen in the harbour is the Great Seam of the Edge Coals. It is now proved, however, that the harbour seams belong to the true Coal Measures, and that the Great Seam is 1,100 feet below the surface at this point. No such depth could have been reached with the old methods of working, apart altogether from the difficulties of drainage, so that there still remains an unworked area of the Great Seam on the mainland of East Lothian. How far it extends inland can only be proved by deep bores, and in such obscure ground it is possible that it might be interrupted at a short distance from the coast by some unsuspected fault.

Dr. Crampton. *Temple District.*—The examination of the natural sections, taken in conjunction with the data obtained from the numerous bores put down by the Arniston Coal Company, has rendered it possible to construct a generalised section of the beds which come above the thin limestone which is taken as the top of the Lower Limestone Group.

Near the bottom of the section there is a coal with a Parrot band, which is probably the Parrot Coal of the Arniston Colliery. It is seen in the South Esk above Temple, and also in the bend of the stream below the junction with Redside Burn, and has been struck in several of the bores of the Arniston Coal Company. The four-feet coal near the top of the Temple section is supposed to be the Kailbaldes seam.

Higher than any of the strata in the foregoing section are some of the beds, with thin coals, which are seen in the little burn running down from Redside, and which cannot be far south of the south-westerly continuation of the Vogrie big fault. A good many still higher beds of the Edge Coal Group, as well as all the beds of the Upper Limestone Group have probably been cut out in this

locality by the same fault, and the thickness of the beds belonging to the Edge Coal Group which are anywhere preserved between Yorkston and Redside, perhaps, does not exceed 200 feet. Owing to their gentle dip, the beds, however, cover a wide area.

Upper Limestone Group.

No beds belonging to this group are seen anywhere on the S. side of the Mid Lothian coalfield, between Temple and Kirkettle, and it is believed that they are cut out by a fault with a large downthrow, to the north,—probably a continuation of the Vogrie big fault. Messrs. Clough, Crampton, and Anderson.

Area between Arniston Mains, Gorebridge, and Smeaton.—Limestone No. 4 is only seen at the surface in one place in this district and this is at Gorebridge, in the burn a little above the bridge, where the top is characterised by many specimens of *Productus latissimus*.

In the Emily shaft, nearly a mile further N.E., this limestone is about 4 feet thick and about 145 feet above the Great Seam. About 187 feet of rock above the limestone is gone through, but no higher limestone.

In the Gore Water almost due north of Harvieston Mains there is a Parrot shale, at least one foot thick, which must intervene between Limestones No. 4 and 5, and is probably in a nearly middle position. This shale was formerly worked to a considerable extent, chiefly from the old Gore pit, and is said to have been a first class gas producer, but to have yielded no coke.

Limestone No. 5 is exposed in Gore Water at the old bridge 550 yards above the foot bridge, and again at the side of the stream a little further up.

Limestone No. 6 is seen in the South Esk in two places above the foot of Gore Water. It contains broken fragments of crinoids, weathers with a yellow crust, and is perhaps about six feet thick, but the lower portion is impure.

Joppa and Gilmerton. Limestone No. 6 can be seen on the shore at Joppa where it is divisible into three parts as follows :— Messrs. Gibson and Bailey.

	Ft.	In.
Dolomitic limestone	5	0
Dark shale	3	6
Blue earthy limestone	4	6

At Niddry the Upper Limestone group includes four calcareous horizons and is more than 1,000 feet thick : an excellent section being visible in the Niddry railway cutting.

Port Seton.—On the E. side of Port Seton a fourth thin limestone has now been found further east and stratigraphically lower than the three previously mapped. It is known that an old pit sunk almost on the outcrop of this lowest limestone, reached the Great Seam of the Edge Coals at a depth of 14 fathoms, so that it is certain that all these limestones belong to the Upper Limestone Group. It is also possible that these four limestones represent the four that Mr. Bailey.

Mr. Bailey. have been shown, during the present revision, to exist in the Niddry railway cutting and at Gilmerton. Both in the Port Seton and Joppa sections *Productus latissimus* occurs in both the third and fourth limestones from the top, but is more abundant in the third than in the fourth.

The total thickness of the group in this locality is not much more than half the thickness at Newbattle, about nine miles distant, and considerably less than a third of that at Niddry, about seven miles distant.

ROSLIN SANDSTONE SERIES.

Messrs. Clough and Gibson. Under the above title, are now included all the beds which come above Limestone No. 6 and the first tolerably good coal, or an equivalent horizon belonging to the true Coal Measures. Thus the series comprises, at various localities, rather more beds than were formerly mapped as Millstone Grit, because the base of this division in the old map was often drawn above the No. 6 Limestone, so as to exclude some beds in which there is a considerable proportion of shale. At Portobello and Gilmerton, however, the base was taken at the top of the limestone. The Roslin Sandstone Series, as now defined, includes, therefore, rather more shale than the old subdivision of the Millstone Grit, but contains a large proportion of coarse pebbly grit, and is singularly barren of good coals though rich in fireclay and coal seats.

Mr. Tait has collected a large number of plants from different beds in this series which have been determined by Mr. Kidston, who has come to the conclusion that within the series there is a palæontological boundary line between the strata containing Upper and those containing Lower Carboniferous plants. The break is not of an absolutely definite character, for *Lepidodendron Veltheimianum*, which was hitherto supposed to be confined to Lower Carboniferous rocks in this country, has now been found at Levenhall in beds which are regarded as Upper Carboniferous. And in a somewhat similar manner *Lepidodendron Glincanum* (Eichwald) has been found in the South Esk near Carrington Barns, in a bed which seems separated from a certain lower marine horizon by a greater thickness of strata than is a bed which in an adjacent part of the river contains Upper Carboniferous plants and fishes. Mr. Kidston regards these two species of *Lepidodendron* as "wanderers," or species which have survived in this area longer than the other Lower Carboniferous plants. It is perhaps surprising that such "wanderers" have not been found in greater abundance, when it is borne in mind that there is no satisfactory evidence of unconformity in the series, and that the beds on either side of the break are of much the same lithological character.

Dr. Traquair has also examined the fish remains which have been collected, and the evidence thus obtained supports so far as it goes Mr. Kidston's conclusions.

In various places a considerable thickness of strata intervenes between the lowest bed yielding Upper Carboniferous plants and the highest bed with Lower Carboniferous plants, and the strata vary considerably in lithological character from place to place. The palæontological break seems, however, to occur near a marine horizon, found by Mr. Tait, consisting generally of one or two beds of nodular ironstone or limestone, which, at Joppa, is about 325 feet above Limestone No. 6, while in the South Esk it probably varies between 150 and 242 feet above. Messrs. Clough and Gibson.

Other marine horizons have been found by Mr. Tait in the Roslin Sandstone Group. At Levenhall, for instance, there are three, the topmost being a shale containing ironstone nodules, which lies about 100 feet below the base of the Coal-Measures. The middle one consists of a red and yellow nodular limestone, from four to six inches thick, containing cup corals and *Bellerophon*, and underlain by a marly shale or fireclay with *Spirifer*, etc. The lower horizon consists of impersistent courses of nodular ironstone and limestone in a fossiliferous shale.

Area between Carrington and Smeaton.—There are good sections in the lower part of the series in the South Esk, for a quarter of a mile below, and about a mile above, the junction with Gore Water, but some of the beds are very inconstant in thickness. Rather more than a third of a mile south of the junction of the Esk and the Gore Water a W.N.W. fault, with a considerable downthrow to the north, crosses the Esk, and the beds on either side of the fault cannot be correlated with confidence. Mr. Clough.

On the N.N.E. side of the fault a marine band, which there consists of red nodular sandy limestone with *Spirifer*, corals and crinoids, occurs about 242 feet above the No. 6 Limestone, and about 87 feet below the beds yielding plants and fishes of Upper Carboniferous type. On the S.S.W. side a marine band which is composed of shale with ironstone nodules with marine fossils is 150 feet above the No. 6 Limestone and 167 feet below the plant bed with *Lepidodendron Glincanum*. In these sections the nodular limestone and nodular ironstone are probably on the same horizon.

Joppa and Musselburgh.—The beds between Limestone No. 6 and the seven-feet coal at the base of the Coal Measures have been measured on the shore at Joppa with the help of Mr. Tait, and the total thickness is estimated to be about 740 feet. Mr. Tait finds two bands of ironstone with marine fossils at 250 feet above the limestone and about 410 feet below the seven-feet coal. The highest horizon at which Lower Carboniferous plants have been met with by Mr. Tait lies about 490 feet below the seven-feet coal. Mr. Gibson.

On the shore at Musselburgh, the low angle of dip and the false-bedded character of the sandstones does not permit accurate or detailed measurements, but the following approximate thicknesses may be given. The seven-feet coal is underlain by false-bedded sandstones and shales about 100 feet thick. Below this come about 25 feet of shales with an ironstone band containing marine fossils,

Mr. Gibson. while at the base an impure coal yields plants of Upper Carboniferous age. A coarse grit, about 100 feet thick, and forming Westpans rocks dips under these beds. Near the summit, a specimen of *Lepidodendron Veltheimianum* can be seen at low water. The grit is underlain by shales and thin grits about 60 feet thick. At the top the marly shales are mottled and contain marine fossils, and near the base a shale yields plants (Plant Bed, No. 1) of Lower Carboniferous species. A few feet above this plant bed a limestone band contains numerous marine fossils.

The mottled beds with limestones and marine organisms have not been found at Portobello, and in fact the two sections do not agree in many respects.

Mr. Bailey. *Niddry.*—In the railway cutting there is a marine limestone about 3 feet 6 inches thick, and 23 feet above Limestone No. 6.

Port Seton.—On the shore east of Port Seton the Roslin sandstone appears west of the four little limestones of the Upper Limestone Group, and comprises sandstones, shales and fireclays or marls, of peculiar mottled red, white and blue tints, together with a few thin coals and two bands yielding *Productus* and other marine fossils. The upper of the two marine bands is a shale with ironstone nodules, while the lower is a nodular limey ironstone.

The very coarse-grained sandstones with large well-rounded pebbles of vein quartz overlie the upper of these two marine bands.

The same beds begin to re-appear with an easterly dip in the western division of the harbour and continue to crop out for some distance along the shore. The exposure shows both marine beds, but the section is obscured a little distance to the west of the lower of them. The beds on the west are generally somewhat thinner than those on the east.

COAL MEASURES.

Mr. Clough. In the south part of the Mid Lothian Basin the base of the Coal Measures is drawn below the fireclay seat of a coal often called the Jenny Meggat, the lowest coal of fairly good quality above the barren Roslin sandstones. In the north part, the base is also drawn below the seat of the lowest good coal above this barren series, which near Joppa is the seven-feet coal, and near Cowpits, the six-feet seam.

It is interesting to observe that in the course of the revision a band of shale and ironstone, charged with *Carbonicola robusta*, has been of service in correlating coal seams in different parts of the basin. It occurs one or two feet above the Parrot Rough seam. the latter being 130 feet above the Jenny Meggat coal near Whitehill Colliery. It was detected during the present revision by Mr. Gibson, but was known to the late Mr. James Bennie many years ago. A similar band occurs above the 15-feet coal of Joppa and has been found by Mr. Tait above the same coal in the Klondyke pit (Niddry) where it has yielded both *Carbonicola robusta* and *Carbonicola acuta*, as determined by Dr. Wheelton Hind. It likewise occurs above the lowest coal in the lately discovered little

basin of Coal Measures at Port Seton. Mr. David Milne Home* notes the appearance of a similar band above the three-feet coal of Cowpits. It is believed that the bands at all these localities are on the same geological horizon, though the intervals which separate this horizon from what has been mapped as the top of the Roslin Sandstone Series vary greatly in thickness. Mr. Clough.

Area between Smeaton and Barleydean.—The pits at present working, at Whitehill, Polton, and Glenesk, have been opened since the original survey of that district. An additional section of considerable value is afforded by the railway cutting at Broomieknowe, and a re-examination of some natural sections, particularly those at Elginhaugh (Melville Castle) and Newbattle Abbey, has led to the identification of various seams, and enabled them to be mapped where they were not shown before. Our knowledge of the eastern part of the district is still, however, very incomplete.

Near Elginhaugh, we find a little above the base of the series, the Jewel Coal, overlaid by the Parrot Rough, Splint and Rough seams, and a still higher seam which is separated from the Rough Coal by about 30 feet of massive yellow sandstone and some fireclay. Of this highest seam only 15 inches is visible, but it seems probable that it corresponds to the Great Seam of Whitehill, as at Polton Colliery this seam is much mixed with shale and of poor quality, and in two boreholes near Glenesk it is represented by a thin coal only from one to four inches thick.

The Jewel seam is not now exposed in the Esk, but its position is known, and it is seen at the entrance of an old day level a little distance south of the river. It is here about 33 inches thick, and lies a little above a massive, coarse sandstone,—the same sandstone as is seen below this coal at the Broomieknowe cutting, and in the burn section 300 yards east of Roslin Castle.

The section of the Parrot Rough coal at Elginhaugh is about four feet thick, and in the middle includes a seven-inch seam of Parrot shale which is very persistent in the southern part of the basin, being seen at Newbattle Abbey and Bromieknowe, as well as in the Polton and Whitehill Collieries. This shale was formerly roasted in retorts to make oil, and sent to the Edinburgh gasworks, and it is still used in the Rosewell gas works.

The best section near Newbattle Abbey is in the little stream which runs into the Esk close to the Abbey. Here the Rough Coal is seen immediately under a thick yellow massive sandstone, representing the sandstone which is usually called the Rough Coal post. Below this coal there are indications of the Splint Seam, underlaid by the Parrot Rough, without any indications of the *Carbonicola* band above it, but with a Parrot shale, about six inches thick, at the base. The Jewel coal of Whitehill and Polton is not

* "Memoir on the Mid Lothian and East Lothian Coalfields," p. 18.

exposed in this locality, and it is doubtful whether it exists. It is stated that in the western portion of the Whitehill workings this coal is also missing.

Mr. Clough and Mr. Anderson

On the east side of the South Esk and about 160 yards S.S.W. of the Abbey there is a coal, at least three feet thick, resting on 21 inches of fireclay, which overlies the yellow sandstone already spoken of as the Rough Coal post. This coal is, in all probability, the Great Seam of Whitehill.

In Aitkendean, near Carrington, there are several exposures of coal, and old abandoned day levels and shallow pits. One of the exposures shows a bright coal which resembles the Rough Coal in quality, and in being directly overlain by a thick massive sandstone, rather coarse and either red or yellow in colour.

Above the horizon of the Great Seam of Whitehill come the Dalkeith Under and Upper seams together with coals formerly worked near Woodburn and Smeaton.

It has now been proved that the coals formerly worked in the old Dean pit, a quarter of a mile west of Carberry Tower, belong, —not to the Upper Limestone Group, as formerly supposed, but to the Coal Measures, and from a bed in the neighbouring Dean Mr. Tait has collected fish scales which Dr. Traquair has found to belong to *Coelacanthus elegans*,—a fish which has never been found below the Coal Measures. These coals are separated from the Edge coals on their north-east side by a big fault with downthrow to south-west,—a continuation of the fault which runs south-east from Monktonhall.

The Jewel, the Beefie, and the Splint seams of Craighall were formerly mined at Smeaton, but neither these, nor any of the measures between them, are now exposed in the district under description, and not much information about them has been procured. It is difficult to understand the physical disposition of these beds in relation to the measures above them. In the old plans a level course in the Beefie seam proceeds in a direction slightly west of north, though the overlying beds in the South Esk, hardly a quarter of a mile further west, are striking nearly east and west.

The unproductive high measures on the north side of the Sheriffhall great fault, that crosses the basin in a nearly east and west direction, are well exposed in Dalkeith Park (in both the Esks), and also in the North Esk for a little distance above the Park. Near the junction of these streams, and above it for about half a mile in each, the general dip is nearly S., often at angles between 9° and 16°, and there is evidence for 600 feet of beds without any coals excepting two, neither of which is usually more than a foot thick. The beds which come above the coals are probably more than 400 feet thick, and most of them are rather coarse-grained, or occasionally pebbly, sandstones of a reddish colour. With these are mixed red, lilac and grey mottled clays and shales, and at least two thin calcareous zones, the lowest containing remains of *Spirifer*. The red measures above the coals resemble the upper barren measures

of Fife (Red Sandstone group), which are classed with the Middle Coal Measures of England,* but no sufficient palæontological evidence has yet been procured in Mid Lothian to determine their age.

Niddry and Musselburgh.—Of the Coal Measures in this area little is seen at the surface, but the new sinking of the Niddry Collieries at Olive Bank, Musselburgh, is of special interest, as it starts in measures high up in the sequence. A coal, between four and five feet thick, which has been cut in an adjacent bore at a depth of 615 feet, is probably the Splint seam of Craighall, as there is a "mussel rib" immediately above it. Mr. Gibson.

Port Seton.—Mr. Tait has shown that a continuous section can be traced westwards from the thin limestones east of Port Seton through the Roslin Sandstone Series into beds of Coal Measure age, which occupy a small basin in the haven of Port Seton. This basin is probably closed to the north very soon after it is lost sight of under the sea, and it does not extend far inland. It contains several coal seams, two of which are important, one measuring 6 feet 4 inches, and the other 7 feet, in thickness. Mr. Bailey.

The presence of two important coals near the base of the Coal Measures at Port Seton is specially satisfactory, since reasoning from analogy, from the case of the deterioration eastwards of the Edge Coals, it might have been supposed that the seams in the Coal Measures so far east as Port Seton would prove much inferior to their Mid Lothian equivalents.

PLEISTOCENE AND RECENT.

Area of Haddington and Fala.—Reference was made in last year's Summary of Progress to the probability that the supposed outlier of Carboniferous Limestone at Kidlaw might prove to be an ice-borne mass. The evidence obtained last season entirely supports this view, for the rocks seen in the Birns Water, a little distance to the west, greatly resemble the red sandstones at Whittinghame, from which Mr. Macconochie has recently obtained remains of *Holoptychius nobilissimus*. It is probable, therefore, that the sandstones of the Birns Water are of Upper Old Sandstone age, and that the limestone at Kidlaw is a transported mass. Moreover to the west, the Boulder clay is full of limestone fragments, and a mile east of Fala two small masses of limestone occur to the south of the Lammermuir fault and resting upon the Upper Old Red Sandstones. They were noted by Mr. Charles McLaren† and by Mr. D. Milne Home ‡ about sixty years ago. These authors supposed an outcrop of limestone occurred here, but the former remarks Mr. Bailey.

* "The Geology of Central and Western Fife and Kinross," Mem. Geol. Survey, p. 146.

† "Sketch of the Geology of Fife and the Lothians," p. 74.

‡ *Op. cit.*, p. 103.

Mr. Bailey. that he saw none in place. The larger of the two masses, though much smaller than that at Kidlaw, was formerly quarried for burning.

Near Fala the Boulder clay is black with comminuted coal, and about half a mile west of the village, the fragments are so numerous that in the original one-inch geological map a coal crop has been drawn at this locality, but it is certain that these pieces have all been transported. Besides such fragments of coal, the Boulder clay in this district usually contains many blocks of Carboniferous Limestone, which must have been derived from a westerly or northerly source. Where it rests on Carboniferous strata to the north of Fala no greywacke fragments are found, whereas the Silurian hills to the south are plentifully strewn with debris of Carboniferous rocks. If, however, the composition of the glacial gravels of the region be examined, they are found to contain a notable proportion of materials derived from the Lammermuirs, even when they are a mile and a half from the nearest Silurian outcrop. Consideration of these facts lends strong support to the opinion that the Boulder clay is a product of land ice.

There is no evidence that the Lammermuirs supported independent glaciers as the period of extreme cold passed away.

On the other hand there is abundant evidence that as the ice-sheet retired from the Lammermuirs, lakes were formed between the ice-margin and the hill slopes. A lake of this nature must have extended from Kidlaw far to the West, even past Fala, a distance of about six miles: the former presence of which is indicated by the evenly bedded gravels, sands and brick-clays which were deposited along its floor. That the ice sheet bounded the lake on the north side is apparent, because,—(1) the surface of the ground could not have formed the barrier,—(2) sections of the drift furnish evidence of the proximity of the ice-sheet during the silting up of the lake.

The records of two sections, exposed in precipitous bluffs rising above the Keith Water about a mile and a half to the north of Fala, are given below: although the two sections are a mile apart, the lowest sand mentioned in each has been traced continuously from the one to the other :—

6. Base of thick sands 5. Boulder clay, 3 feet 4. Sand, 47 feet	Upper members not seen in this section.
3. Boulder clay, 13 feet	Boulder clay, 6 feet.
2. Sand, 15 feet	Sand, 65 feet.
1. Boulder clay, 37 feet (at the base)	Boulder clay, 33 feet.

These sections allow us to form an idea of the oscillations by which the retreat of the ice-sheet was affected. As the ice retired a marginal lake appeared, into which the Lammermuir streams and the melted waters of the glacier poured detritus: and then, during a temporary increase in the severity of the seasons, the ice-sheet would advance again for a while and spread out upon the lake bottom a layer of Boulder clay.

Mr. Bailey. Further evidence in support of the existence of this lake is to be found in the channel by which its waters escaped, which still separates Kidlaw from the Lammermuirs. For the most part of its length it is now no longer a watercourse, though it still retains all the characters of a stream-cut valley. Other examples of similar overflow channels abound in the district and correspond exactly to the "dry valleys" described by Professor Kendall in the Cleveland District of Yorkshire.*

Mr. Clough. *Area between Smeaton and Newbiggin.*—A section about 150 yards north of Eskbank railway station shows coarse gravel over-lying eight or nine feet of fine sand and stoneless, often finely laminated, clay. Similar clay and sand are seen in the cutting half a mile south of the station, and are covered by a reddish brown boulder clay. Three quarters of a mile S.S.E. of this cutting similar clay and sand are again seen covered by boulder clay, in the old clay pits of Newton Grange. These pits are a little under the 250 feet contour and about the same level as the Eskbank exposure, and it seems probable that the sand and stoneless clays mentioned were at one time continuous before the valley of the South Esk was formed.

At least three valleys which run almost parallel with the contour lines, and which are now either dry or occupied by insignificant streams, occur between Rosewell and Redside, one of them extending more than three miles. In various places they have glacial gravel on both sides and appear to have been cut out of it, but probably at periods when a direct drainage to the north was impossible owing to the presence of some ice barrier.

Mr. Clough and Dr. Crampton. Between Lawfield and Crossgatehall we find a number of slight surface features which run nearly parallel to the contours in a general north-east direction. One of these passes near Langlaw and Fuffet, and developes at its northern end into a valley which cuts deeply across some rising ground, which has perhaps at one time formed part of the watershed between the Esk and the Tyne.

The landward margin of the 100-feet raised beach is not well-defined in this district, but it appears to rise gently in a southerly direction, and at Cowden Foot to be more than 150 feet high. The south limit is very indefinite. The surface of the gravel which forms the top deposit under a great part of Dalkeith, slopes gently N.N.E., and this gravel perhaps represents a fluviatile deposit which was being formed at the same time as the beach.

In Dalkeith Park the 100-feet beach deposits, and other older beds, have been carved into a series of river terraces which are very distinct. The highest terrace is about 20 feet below the top of the beach, and at least five other lower river terraces are preserved in that area.

Mr. Bailey. *District between Musselburgh and Sheriffhall.*—Some beautiful examples of eskers occur in the neighbourhood of Sheriffhall.

* "On a System of Glacier-Lakes in the Cleveland Hills": Q.J.G.S., 1902, p. 471.

It has been found possible to map the margin of the 100-feet raised beach from the east side of the Esk westward to Edinburgh. Its height above Ordnance datum is about 130 feet. At Duddingston, and to the east of Craigmillar Castle, large alluvial flats occur a little above the level of the raised beach, which probably owe their origin indirectly to the former submergence of the land.

Mr. Anderson.

Prestonpans.—In the drift-covered areas a little south of Prestonpans, Boulder clay seems always present as a substratum, but is sometimes covered by glacial sand.

Below the 100-feet level the ground is mostly covered by sandy raised beach deposits.

PHYSICAL AND ECONOMIC FEATURES.

Messrs. Clough, Crampton, Bailey, and Anderson.

The central portion of the Mid Lothian basin may be described generally as a plain sloping gently towards the N.N.E. between the Pentland Hills on the west, and the lower hills of Falside, Cousland and the Roman Camp on the east. The plain corresponds to an area which has been sunk below the level of the ground on either side during the course of earth-crust movements, but the extent of these differential movements was very much larger than the present difference in height between the plain and the marginal hills; indeed, when we come to examine the area closely, we find that some lines of large dislocation,—such as the Sheriffhall fault and the Vogrie fault,—cross it, without, as far as can be seen, having the least influence on the present surface configuration. It is clear, too, that the nearly uniform N.N.E. slope of the plain does not indicate an equally uniform pitch of the syncline, because for a considerable distance north of Dalkeith the general inclination of the strata is in a southerly direction, and at rather high angles.

Coal mining is one of the chief industries of the district, and there is every indication of important developments in the early future. Brickmaking is carried on at various collieries, including Whitehill, Arniston, Newbattle, and Prestongrange, the material used being either shale, procured in the course of "brushing" the underground roads, etc., or underclay, or mixtures of these materials. At Prestongrange, one of the coals, called the clay seam, is chiefly worked for the sake of the underclay, about two feet thick, which underlies it. At Whitehill the fireclays chiefly used are got below the Great Seam and the Jewel Seam. At Arniston the clay under the Kailblades coal is said to be the best.

The mottled red-brown and purple clays, which occur on the north side of the Sheriffhall fault at Dalkeith, have a close resemblance superficially to the marls which lie above the *Etruria* beds of North Staffordshire, and which are so much used in the manufacture of the Staffordshire blue bricks, but whether they are of an equally good quality remains to be proved. They occur in beds of considerable thickness, but in a somewhat disturbed area, and

excepting in Dalkeith Park, they are probably confined to the precincts of the town, where perhaps they could not be conveniently worked. Messrs. Clough, Crampton, Bailey, and Anderson.

The limestone which comes to the surface along the arch of the anticline between Hillhead and Cousland is at present much less worked than formerly, but at West Houses it is being mined in a day level by the Newbattle Coal Company, and carried thence to kilns at Bryans. At Cousland a new company has lately erected plant for making hydraulic lime.

The chief sandstone quarries at present being worked in the southern part of the district consist of the following,—two in the Coal Measures at Bonnyrigg, one in the Coal Measures near Barleydean, and one in the Edge Coal group near Easthouses: one of those at Bonnyrigg is in the freestone which underlies the Jewel Coal, and the other is probably some distance above the Great Seam. Many old quarries are not at present being worked, but some of these are probably opened up from time to time to suit the local requirements. The largest of these are near Cowden and appear to be in the thick sandstone which overlies Limestone No. 4. South of Prestonpans a sandpit has been worked for two or three years close to the railway, in an accumulation of sand which is probably of glacial origin.

Most of the land at levels under 500 feet is under cultivation, and, with the aid of heavy manuring, gives excellent crops. Near Musselburgh and Prestonpans a great deal of the low ground is covered by sandy raised beach deposits, and has been turned into market gardens.

Most of the district is supplied with water by the Edinburgh and District Water Trust, which has large storage reservoirs in the southern part of the district. The village of Lasswade obtains a supply from fluvio-glacial gravels on the north-west side of the Esk a little below Melville Castle. Dalkeith obtains part of its supply from the Edinburgh and District Water Trust, and an additional quantity from three boreholes near Lugton Bridge, and from fluvio-glacial gravels near Elginhaugh and Viewfield. The wells in the last-mentioned locality are said to be 150 years old. About two miles south-east of Rosewell a reservoir of considerable size has lately been made to collect gravitation water for the use of Roslyn Asylum. Prestonpans is to be provided with water from a reservoir which has been constructed at Kidlaw, on the border of the Lammermuir Hills.

The water which is encountered in the coal mines is generally so charged with iron salts or with sulphates, formed through the oxidation of iron pyrites, that it is not suitable for domestic use. And, for a similar reason, if bore-holes were made for water through beds containing many coal seams, it would probably be necessary to tube portions of the holes, so as to keep out deleterious affluents.

II. PALÆONTOLOGICAL WORK.

r. B. N. each.

The palæontological department in Scotland has been carried on under the general charge of Dr. Peach, Acting Palæontologist. by Dr. C. B. Crampton, assisted by Mr. A. Macconochie and Mr, D. Tait. Much valuable assistance has, as formerly, been given by the following specialists outside the Geological Survey, viz., Dr. R. H. Traquair, Dr. Wheelton Hind and Mr. R. Kidston.

The total number of fossils collected and entered in the official list books is 3,347, most of which have been obtained from the Carboniferous rocks of the Lothians and Berwickshire in connection with the revision of the coalfields. In view of zoning the Carboniferous rocks the attention of Messrs. Macconochie and Tait was specially directed to collecting fossil plants and fishes as such organisms have been shown to be favourable for this purpose.

A preliminary examination of most of the fossils collected was made by Dr. Peach prior to their being distributed for determination. The fishes have been submitted to Dr. Traquair, the plants to Mr. Kidston and the lamellibranchs to Dr. Wheelton Hind. The other palæozoic fossils have been retained in the Edinburgh office, while the Mesozoic and Tertiary fossils have been sent to Mr. E. T. Newton.

The researches of Dr. Traquair and Mr. Kidston regarding the distribution of the fish fauna and of the plants respectively, have made it apparent that the palæontological line between the Upper and Lower Carboniferous rocks must lie within the limits of the Scottish Millstone Grit. The revision of the Mid Lothian basin has, therefore, afforded a favourable opportunity of testing the point within the Roslin Sandstone Series which has hitherto been considered as the equivalent of the Millstone Grit. The Roslin Sandstone Series, according to the classification of the Geological Survey embraces all the strata that lie between the No. 6 Limestone (Castlecary limestone), and the Seven Feet Coal or an equivalent horizon, which is regarded as the base of the Lower Coal Measures (see p. 110.) With the above special object in view a rigorous search for fossils was made by Mr. Tait, more especially for plant remains in all the exposures of the Roslin Sandstone group around the Mid Lothian basin. In this work Mr. Tait has not only been in touch with the officers of the Geological Survey, working in the separate areas of the district, but has also had the invaluable advice and assistance of Mr. Kidston. It has been found that the Lower Carboniferous plants and fishes extend up into the Roslin Sandstone for about one-third of its thickness and that with the exception of two species of plants, the rocks of the upper two-thirds of the series have as yet only yielded Upper Carboniferous forms. The following list of plants and fishes from the various localities, determined by Mr. Kidston and Dr. Traquair respectively, illustrates this point :—

No. 1 List of fossil Plants and Fishes from the lower third of the Roslin Sandstone series:— Dr. B. N Peach.

Plants.

Sphenopteris elegans, Brongn.
Sphenopteris Linkii ? Goepp. sp.
Calamites Haueri, Stur. sp.
„ *ramifer*, Stur.
„ n.sp.
Sphenophyllum tenerrimum, Ett.
Lepidodendron glincanum, Eichw.
Lepidodendron rhodeanum, Sternb.
Lepidodendron veltheimianum, Sternb.
Sigillaria canobiana, Kidston.
„ *Taylori*, Carr.
„ *cf. undulata*, Goepp.
Lepidostrobus variabilis, L. & H.
Stigmaria ficoides, Sternb.
„ *stellata*, Goepp.

Fishes.

Rhizodopsis (indistinguishable from *R. sauroides*. Will.)
Callopristodus pectinatus, Ag.
Elonichthys Robisoni ? Hibb.

All the above are Lower Carboniferous forms with the exception of *Rhizodopsis sauroides* which is found in the Coal-measures and *Callopristodus pectinatus* which is common to both Lower and Upper Carboniferous Rocks.

No. 2 List of fossil Plants and Fishes from the Upper two-thirds of the Roslin Sandstone:—

Plants.

Alethopteris lonchitica, Schloth. sp.
Mariopteris muricata, Schloth.
Neuropteris gigantea, Sternb.
„? *heterophylla*, Brongn.
Sphenopteris obtusiloba, Brongn.
Calamites Suckowii, Brongn.
Calamocladus equisetiformis, Schloth. sp.
Annularia radiata, Brongn.
Sphenophyllum cuneifolium, Sternb.
Lepidodendron aculeatum, Sternb.
„ *glincanum*, Eichw.
„ *obovatum*, Sternb.
„ *veltheimianum*, Sternb.
„ allied to *Gaudryi*, Renault.
Sigillaria elegans, Sternb.
Sigillaria scutellata, Brongn.
cf. Sigillaria Sillimanni, Brongn.
Lepidostrobus cf. variabilis, L. & H.
Stigmaria ficoides, Sternb.
„ „ var.
Cordaites principalis, Germar, sp.
Cordaianthus Pitcairniæ, L. & H. sp.

Fishes.

Pleurodus Attheyi, Barkas.
„ *Rankinei*, Hancock and Atthey
Rhadinichthys monensis, Egerton

r. B. N. ach.

The plants and fishes shown in the above list are all Upper Carboniferous forms with the exception of *Lepidodendron glincanum* and *L. veltheimianum*, but even these appear to die out within the upper two-thirds of the Roslin Sandstone. *Lepidodendron veltheimianum* is one of the most characteristic forms of the Lower Carboniferous series, and was at one time thought by Mr. Kidston to be confined to that part of the formation, but he finds that on the continent it passes up for a little way into the upper division and is associated with Upper Carboniferous forms as in the present instance. *Lepidostrobus variabilis* and *Stigmaria ficoides* appear in both the above lists, but the former being only the fruiting spikes, and the latter, the underground rhizome, of more than one Lepidodendroid plant, may therefore be disregarded as having no bearing upon the question at issue.

In addition to the fixing of the position of the above important palæontological line, the fossils collected from the Roslin Sandstone group have made it clear that marine conditions of deposit did not cease with the deposition of No. 6 Limestone (Castlecary Limestone). Several marine zones have been observed at various levels up to over 200 feet above that band. The following list of characteristic marine fossils, determined by Dr. Crampton and Dr. Wheelton Hind has been collected from a bed exposed in Arniston Glen near Gorebridge at about 242 feet above No. 6 Limestone :—

Crinoid stems.
Archæocidaris Urei, Flem.
Fenestella sp.
Camarophoria ?
Discina nitida, Phill. (very large.)
Orthotetes crenistria, Phill. (abundant.)
Orthis Michelini ? Lev.
Productus costatus, Sow. (abundant.)
,, *giganteus*, Martin.
,, *semireticulatus*, Martin.
Spirifer trigonalis, Martin.
Bellerophon, sp. (abundant.)
Murchisonia like *angulata*, Phill.
Aviculopecten dissimilis, Phill.
Cypricardella acuticarinata, Armstrong, sp.
Edmondia, sp.
Leiopteria Thompsoni, Portlock, sp.
Limatulina simplex, Phill. sp.
Parallelodon Geinitzi, de Kon.
Protoschizodus axiniformis, Portl.
Pteronites angustatus, M'Coy.
Schizodus antiquus, Hind.
Sedgwickia gigantea, M'Coy.
Solenomya costellata, M'Coy, sp.
Discites, sp.
Goniatite.

A band of clay ironstone which occurs at a slightly lower level is characterised by the abundance of a variety of *Orthotetes crenistria*. A peculiar small highly arched form of *Productus giganteus* occurs in another band in this part of the Roslin Sandstone while another

ironstone holds unusually large individuals of *Discina nitida*. The most of the marine bands occur below the level at which the Upper Carboniferous plants begin to appear. Dr. B. N. Peach.

With a view of determining the geological horizon of an impure shale that overlies the volcanic platform of North Berwick and the Garlton Hills, and which is exposed on the shore east of Gullane in Haddingtonshire, Mr. Macconochie made a collection of fossils, chiefly fish remains, which have been examined by Dr. Traquair, who has kindly furnished the following notes regarding them.

"A number of fossil fishes and fish remains, collected by Mr. Macconochie from a shale exposed on the sea shore about two miles to the north-east of Gullane, having been entrusted to me for determination by the Director of the Geological Survey, I herewith submit the following notes:— Dr. Traquair.

1. *Acanthodes* sp. A few fragments, not specifically determinable.

2. *Rhizodus Hibberti*, (Ag.) Two scales, of which one is three inches in diameter.

3. *Gonatodus punctatus*, (Ag.)—Dentary bone of right mandible showing the peculiar dentation.

4. *Elonichthys Robisoni*, (Hibb.)—A considerable number of fragments, but no perfect fishes.

5. *Elonichthys striatus*, (Ag.)—Many specimens, some nearly entire.

6. *Elonichthys striatulus*. n.sp. Traq.—The length of the single specimen may be estimated at 21 inches, the top of the caudal fin and also of the snout being cut off by the edges of the stone. Dorsal fin proportionally large, situated about the middle of the back, its rays are slender with distinct articulations; caudal fin, heterocercal, bilobate and with rays similar to those of the dorsal fin fulcra few, very oblique. Scales of the flank ornamented with ridges which pass across the exposed surface from front to back in a direction mainly parallel with the upper and lower margins, and show a certain appearance of imbrication from above downwards; in many cases the ridge is double, the two divisions uniting close to the posterior margin of the scale. This species is distinguished from all the others of the genus by its scale ornament, and by the fin fulcra, which, so far as can be seen, are few, oblique and elongated.

On looking over recently some undetermined Eskdale material in the collection of the Museum of Science and Art, I found a small fish from Glencartholm, which I am unable to distinguish specifically from the above described Gullane specimen, as, though slightly larger, it displays the same general form, along with the same character of the scale-ornament and of the fulcra.

7. *Rhadinichthys ornatissimus*, (Ag.)—One fragmentary specimen.

8. *Rhadinichthys brevis*, Traq.—To this species I refer some small fishes, of which one is a perfect specimen.

Dr. Traquair

9. *Rhadinichthys elegantulus*, Traq. This is a small and not quite perfect specimen, but as it stands I cannot distinguish it from *Rh. elegantulus Traq.* the most common fish in the Glencartholm fish-bearing shale.

10. *Rhadinichthys formosus* n.sp. Traq.—The only specimen of this beautiful species is unfortunately not perfect, nearly the whole of the upper and a great portion of the lower lobe of the caudal fin being lost. As it is, the length is 3¾ inches, but when entire the fish must have measured 4½ inches. Head bones finely striated; scales moderate in size, those of the flank showing an ornament which considerably resembles that of the scales of *Elonichthys pulcherrimus* from the Glencartholm beds, the exposed surface being covered with closely set fine ridges, those on the posterior superior part passing obliquely downwards and backwards, while on the anterior-inferior aspect they pass nearly horizontally backwards and parallel to the inferior margin. Position of paired fins indicated but their rays very scantily preserved. Dorsal and anal fins large, triangular-acuminate, the former beginning somewhat in advance of the latter; rays of both numerous, slender, with distinct articulations.

I have placed this species in *Rhadinichthys* owing to its resemblance in external form to *Rh. brevis*, although the condition of the rays of the pectoral fin cannot be ascertained. The resemblance of the ornament of the flank scales to that in *Elonichthys pulcherrrimus* is curious as the rest of the fish is very different.

11. *Wardichthys cyclosoma*, Traq.—This small Platysomid fish has hitherto been known only from two specimens and a few scales from Wardie Beach near Edinburgh, for I must own that my reference to it of certain scales from Liddesdale, originally with a query, is now extremely doubtful. Both of the Wardie specimens are truncated just at the tail pedicle, but of the well-preserved specimens obtained from this new fish-bed, several show the entire caudal fin. This is small in size compared with the proportionally great depth of the body of the fish, and is completely heterocercal and bilobate.

On looking over the above list, it will be seen that all the named species with the exception of three, namely, the two new ones and *Rhadinichthys elegantulus* occur in the Wardie beds. It is also to be noted that *Rhizodus Hibberti* extends up to the Upper Limestone Series (South Parrot Coal); *Elonichthys Robisoni* and *Rhadinichthys ornatissimus* to the top of the Edge Coal group, and *Elonichthys striatus* to the Dunnet Shale. *Gonatodus punctatus* and *Rhadinichthys brevis*, besides occurring at Wardie, are also found in the Pitcorthy shale in Eastern Fifeshire. So that although the fish-fauna of this East Lothian shale, so far as we know it, certainly more closely resembles that of the Wardie Shale than of any other set of beds in the Lower Carboniferous Series of the south of Scotland, it would not be safe to assume from this circumstance alone that this rock is of "Wardie" age.

One remarkable circumstance is that *Eurynotus crenatus* and *Nematoptychius Greenockii* two of the most characteristic estuarine fishes of the Lower Carboniferous of the Edinburgh District, from the Wardie shales below to the South Parrot Coal above, have not been found in the East Lothian bed. It is, however, not easy to account for the absence of certain genera or species from strata where, judging from the other species present, we should certainly have expected to find them. Dr. Traquair

Whatever be the position of this bed in the Lower Carboniferous series of the central valley, it is certainly of great interest to find in it two species, which have not occurred elsewhere except in the Glencartholm shale, Canonbie, and one hitherto known only (with certainty) by a couple of specimens from Wardie."

Mr. Macconochie, while searching the Lower Carboniferous rocks of the Berwickshire coast near Marshall Meadows obtained a suite of fossil fish remains in a dark coaly shale associated with the Lamberton Limestone (identified by the late Mr. Gunn as the Dun Limestone). Dr. Peach.

The following is a list of the forms from these beds as determined by Dr. Traquair :—

Callopristodus pectinatus, Ag.
Pleuracanthus elegans, Traq.
Cynopodius crenatulus, Traq.
Elonichthys, sp.
Rhizodus Hibberti, Ag.
Rhizodus ornatus, Traq.
Megalichthys sp.

The fishes enumerated in the above list are found in the oil shale group of Mid Lothian and show plainly that at the period of the deposition of this band there must have been direct communication between the two areas round the eastern end of the Southern Upland barrier. Similar evidence was obtained by Mr. Macconochie from strata at a lower horizon. This year he collected from beds belonging to the Cement-stone group that underlie the volcanic rocks of North Berwick and the Garleton Hills, exposed along the Haddingtonshire coast, between Dunbar and Tantallan Castle, specimens of higher crustacea, viz :—*Pseudogalathea* (*Anthrapalæmon*) *Macconochei and Anthrapalæmon Etheridgi* which occur plentifully in the Cement-stones of Tweeden Burn in Liddesdale and from the Glencartholm shales in Eskdale.

In a band of Cement-stones of Ballagan type underlying the red tuff at the base of the North Berwick and Garleton Hills volcanic group at a point on the coast east of N. Berwick harbour, Mr. Macconochie obtained specimens of the bivalve phyllopod *Estheria Peachi* a form discovered by the late Mr. David Grieve, and hitherto only known to occur in Cement-stone bands exposed in the "Calmstone" quarry in the Queen's Park, Edinburgh, where the rocks occupy a similar stratigraphical position near the base of the [redacted] canic zone of Arthur's Seat.

Mr. Peach. Mr. Tait, while collecting from the Orcadian division of the Old Red Sandstone of the Black Isle, Ross-shire, obtained a fossil plant stem preserved in such a manner as to exhibit its minute internal structure. It resembles that described, as an early form of pine, by Hugh Miller in his "Old Red Sandstone" and "Footprints of the Creator"* from a specimen which he found enclosed in a nodule from the Cromarty Fish-bed. Mr. Tait collected his specimens from a shale with nodules intercalated in sandstones exposed in the Killen Burn a quarter of a mile south of Killen Smithy and three miles west of Avoch Railway Station. It is enclosed in one of the calcareous nodules, some of which have yielded *Coccosteus decipiens* and other fishes characteristic of the lowest zone of the Orcadian series (Achanarras) as defined by Dr. Traquair. Dr. Horne, who mapped the rocks in this area, is of opinion that this fish-bearing band is higher up in the series than the Cromarty fish-bed above alluded to.

A peculiar interest attaches to the present find as the original specimen described by Hugh Miller is not now traceable. The plant stem has been sliced and handed to Mr. Kidston for microscopic examination and description.

The following is a list of specimens in the Scottish collection figured in the volume of the Palæontographical Society for 1903 :—

BRITISH GRAPTOLITES, PT. III., by Miss G. L. Elles and Miss E. M. Wood, and Professor Lapworth.

Leptograptus flaccidus (Hall). From Mount Benger Burn. Hartfell Shales. Pl. xiv., fig. 1b.

Leptograptus ascendens, Elles and Wood. From foot of Hawkwood Burn, Abington. Glenkiln Shales. Pl. xvi., figs. 6a and 6b.

Amphigraptus divergens, var. *radiatus*, Lapw. From Hartfell Spa. Hartfell Shales. Pl. xviii., fig. 2c.

Amphigraptus distans, Elles and Wood. From Barskeoch Burn, near St. John's Dalry, Kirkcudbrightshire. Hartfell Shales. Pl. xviii., fig. 3.

Nematograptus (*Cœnograptus*) *gracilis* (Hall). From Bail Hill, Sanquhar, Glenkiln Shales. Pl. xix., fig. 1a.

Nematograptus (*Cœnograptus*) *gracilis* (Hall). From Berrybush Hill, St. Mary's Loch, Selkirkshire. Glenkiln Shales. Pl. xix., fig. 1c.

Nematograptus (*Cœnograptus*) *gracilis*, var. *remotus*, Elles and Wood. From Rein Gill, Wandel Water, Lanarkshire. Glenkiln Shales. Pl. xix., fig. 3a.

Nematograptus (*Cœnograptus*) *gracilis*, var. *remotus*. Elles and Wood. From Morrach Bay, Portpatrick. Glenkiln Shales. Pl. xix., figs. 3g and 3h.

Nematograptus (*Cœnograptus*) sp. From Craiglure Lodge, Head of Stinchar. Glenkiln Shales. Pl. xix., fig. 5.

Nematograptus explanatus, var. *pertenius*. (Lap.) Rein Gill, Wandel Water, Lanarkshire, Glenkiln Shales. Pl. xix., fig. 7f.

BRITISH CARBONIFEROUS LAMELLIBRANCHIATA. VOL. II., PT. II., by Dr. Wheelton Hind.

Streblopteria ornata, R.E. jun. From River Gryfe, near Crosslea Mill, Houston. Pl. xi., fig. 10.

Streblopteria ornata, R.E. jun. From Waygateshaw Limestone Pit, Carluke. Pl. xi., figs. 11 and 12.

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* The Old Red Sandstone, 1st ed., chap 5, p. 100, 1841. Footprints of the Creator, 12th ed., p. 194, 1870.

Aviculopecten Eskdalensis, W. Hind. From River Esk, Glencartholm, Calciferous Sandstone Series. Pl. xii., fig. 7. Dr. Peach.

Aviculopecten knockonniensis, M'Coy. From Salton. Pl. xiv., figs. 9 and 10.

Aviculopecten inequalis, W. Hind. From Boness. Pl. xiv., figs. 14 and 15.

Aviculopecten subconoideus, R.E. jun. From Knockhill, Fife. Pl. xvii., figs. 1, 2, 3.

Pseudamusium ellipticum. Phill. From Craigenglen. Pl. xx., figs. 16 and 17.

III. MUSEUM WORK.

Mr. Goodchild, Curator of the Geological Survey Collections in the Edinburgh Museum of Science and Art, reports that during the winter and spring of 1903, the chief work was in connection with the rearrangement of the rock specimens, relating to Sutherland and Ross, and incorporating with them, the specimens of the older rocks of Inverness-shire. The collections relating to Argyllshire were also revised in the same manner. Mr. Goodchild has also been occupied with the revision of the Scottish Mineral Collections, and in the preparation of Part III. of the Guide to the collection of Scottish Geology and Mineralogy. Mr. Goodchild.

III.—IRELAND.

FIELD WORK.

Cork District.

Mr. G. W. Lamplugh, District Geologist.
Mr. J. R. Kilroe,
Mr. A. McHenry,
Mr. H. J. Seymour, B.A.
Mr. W. B. Wright, B.A.
Mr. H. B. Muff, B.A.
} Geologists.

Introduction.—The field-work of the Irish branch of the Survey during 1903 was concentrated upon the mapping of the superficial deposits of the country around Cork. As the sheet-divisions of the existing 1-inch Ordnance map are inconvenient for the purpose, it has been arranged to follow the plan which was adopted for the Belfast district, and to prepare a special "Cork District" sheet on which to publish the results of the drift survey. The limits of this sheet are shown in the accompanying Index-map (Fig. 5); it includes portions of Sheets 186, 187, 194 and 195 of the existing 1-inch map of Ireland. Mr. Lamplugh.

The principal topographical features of this area are the bold east-and-west ridges formed by anticlines of the Old Red Sandstone rocks, with the broad hollows between them occupied by the synclinal infolds of Carboniferous Limestone and Lower Limestone Shales. The southern part of the map consists of one of these ridges ("Southern Anticline" of Index-map), rising toward the west

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to nearly 600 feet above O.D., but sinking lower eastward and there gapped by the broad entrance to Cork Harbour. To the northward of this ridge lies the synclinal hollow of Carboniferous rocks, named by Jukes "The Valley of Cloyne," extending from Ballinhassig on the west to and beyond Rostellan on the east, the wide basin of Cork Harbour occuping the lowest part of this depression. The ground then rises steeply again into the narrower anticline of Old Red rocks, which runs across the central part of the map as a continuous barrier, except where broken by the two transverse gorges of West and East Passage by which a portion of the ridge is cut out to form Great Island. This "Central Ridge" is highest in the west where, within the limits of the map, it rises to over 570 feet.

FIG. 5.

INDEX TO CORK AND CORK HARBOUR SHEET.

Glacial Striæ. Figures; height in feet above Ordnance Datum.

To the northward of the Central Ridge lies the principal valley of the district, that in which the city of Cork is situated and along which from the westward flows the river Lee, the largest stream of the map, until diverted southward through the West Passage into Cork Harbour. This "Valley of Cork"—to use the name adopted by Jukes—is about two miles wide where it enters the map on the west, and becomes still broader eastward after being abandoned by the Lee, being about three miles wide near Midleton where it passes out of the map.

On the northern side of the Cork Valley the Old Red Sandstone rocks again rise up boldly and extend as an upland to the northern margin of the map, though interrupted by a deep

undulation marking the boat-shaped infold of the Lower Carboniferous rocks stretching E.N.E. and W.S.W. from Riverstown, and by a similar but more strongly marked depression due to another infold of these rocks at Blarney. The southern part of this northern upland, south of the Blarney syncline, forms the "Cork and Youghal Anticline" of Jukes, while its more northerly portion represents the beginning of the great "Mangerton Anticline" which embraces all the high land to the north of the map, south of the Bride Valley. This upland is broken by several transverse river-gorges to which further reference will be made. It shows, as a whole, a steady rise toward the north-west, so that a little beyond the northern margin of the map the ground in several places attains to between 650 and 700 feet in altitude. Within the map the highest point reached is 640 feet, but the summits are usually below 500 feet. Mr. Lamplugh.

The remarkable drainage-system of this part of Ireland has long been celebrated by reason of the classical work of Jukes, who showed that the transverse gorges by which the larger rivers escaped southward from one broad lateral valley to another through high intervening ridges must mark the course of the ancient drainage before the lateral valleys were excavated. Without entering into detail it may here be stated that the recent work of the Survey has tended to corroborate the conclusions of Jukes, by proving that all the main transverse valleys were in existence prior to the Glacial Period, though numerous minor modifications of the pre-existing valleys have taken place during and since that period; of which examples will be given in the context. At some period before the glaciation of the district, there appears to have been a great and rapid deepening of the main lateral valleys, so that the grade of the streams descending from the uplands into these valleys was sharply increased and they everywhere began to cut backward into the margins of the uplands with fresh vigour. This process was also renewed during the passing away of glacial conditions. We find, therefore, throughout the district that the side-streams enter the low lateral valleys in deep ravines proportionate in length to the volume of the stream, and that if we follow up any of these ravines to its head, we emerge upon an open shallow valley out of the lower part of which the gorge has been notched. These open upland valleys are part of the mature topography which characterizes all the high ground of the district as soon as we penetrate beyond the immediate influence of the marginal drainage. The smooth flowing outlines of the uplands appear to be the result of pre-glacial erosion and not of glacial denudation.

EARLY-GLACIAL RAISED SHORE.

The discovery of a well-marked rock-shelf with associated deposits of sand and wave-worn shingle, and sometimes of blown sand, banked against an ancient cliff and covered to a considerable depth by local rubble or 'head' and by boulder-clay, throws great light upon the physical conditions of the South of Mr. Wright and Mr. Muff.

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Ireland before its glaciation. This ancient sea-margin lies only a few feet above the present high-water mark; it was found at many points on the open coast between Power Head and Roche's Point, and on the opposite side of the Harbour Entrance, east and south-east of Crosshaven. It has also been recognised in several places around the shores of Cork Harbour, which must therefore have been in existence as an inlet of the sea before Glacial times. Researches carried out unofficially have proved that this old coast-line can be traced at the same level for long distances eastward and westward of the present map, and that in several good sections to the eastward it is seen to be overlain by the marly boulder-clay with far-travelled stones, which is the earliest product of the great glaciation known in the east of Ireland. The presence of a few erratic stones in the ancient beach seems to imply some form of glacial transport either before or during its formation, and the general evidence is in favour of its early-glacial age. An important deduction to be drawn from the presence of this beach is that although there had been a previous period of elevation during which the mouths of the larger valleys were excavated below present sea-level, yet for an interval of considerable duration immediately prior to the glaciation of the country, the land stood at within a few feet of its present level. The full results of Messrs. Wright and Muff's researches into this subject in the South of Ireland have been communicated in a paper to the Royal Dublin Society and will be published in the Proceedings of that society.

GLACIAL DEPOSITS.

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As compared with the Dublin and Belfast areas, in which the drift-survey had been previously conducted, the indications of glaciation in the Cork district are comparatively restricted, but are yet sufficient to show, contrary to expectation, that the whole tract has been covered by land-ice.

The greater part of the drift deposits, both stratified and unstratified, are made up of the debris of the local rocks; and it is only in the exceptional cases to be afterwards mentioned that material known to be foreign to the district has been introduced, though the similarity of the rocks over wide areas in the south of Ireland, westward of the present map, opens up the possibility that some of the drift-material may have travelled for some distance without bearing proof of its extraneous origin.

As usual in glaciated districts, the greatest accumulation of drift is found on the low ground. Thus in the Blarney valley, in the Lee valley and its eastward prolongation to Midleton, and in the Cork Harbour hollow, there are extensive deposits of boulder-clay and glacial gravel, while on the ridges which separate these valleys the drift is as a rule confined to more or less irregular and interrupted patches of clayey rubble containing a few scratched stones. In many places, indeed, it is doubtful whether this upland drift should

be considered as true glacial drift, as it appears to consist mainly of the superficial detritus, only partly of glacial origin, which has gradually accumulated in the hollows and on the gentler slopes, or on the upland flats, from the effect of subaerial agencies since the Glacial period. Such material would be more correctly classed as "Rearranged Drift" (the "Glacialoid Drift" of Kinahan), but in actual mapping it is found impossible to differentiate between this rearranged drift and the glacial drift from which it has been in part derived and with which it is generally very closely associated. Mr. Lamplugh.

On the high ground near the northern edge of the map, however, a rubbly boulder-clay sets in as a more persistent and less uncertain covering to the solid rocks, and is occasionally associated with moundy masses of gravel and sand of considerable thickness, of which some further account will be given in the context. In this tract, also, the rock-surfaces generally show more evident signs of glaciation, the harder beds protruding in irregular knobs with an ice-worn aspect, and sometimes with ice-scoring still recognisable.

To illustrate the general character of the glaciation of the district, some notes on the drift of the above-mentioned physiographical divisions will now be given separately.

Northern Upland.

The boulder-clay flanking the ridge in places and occurring in hollows on the high ground is chiefly made up of angular detritus in a clayey matrix, and differs considerably from the boulder-clay of the Lee valley, which contains a large proportion of sand and rounded pebbles. Most of the hill-drift also shows a complete lack of limestone-detritus, which is abundant in most of the valley drift. The proportion of glaciated stones which it contains is usually small, and these stones are, as a rule, much less severely ice-marked than the stones in the boulder-clay of the valleys. Small fragments of chert, probably derived from the Carboniferous rocks, are the only constituent not occurring *in situ* on the upland which were noticed in this drift in the more northerly part of the map, except in the north-eastern corner, where a few far-travelled boulders were found which appear to have been derived from the erosion of the boulder-clay. Mr. Kilroe.

The presence of small boulders of granite in this quarter, supposed by Jukes to have been transported from Galway, was mentioned in the Survey Memoir published in 1864 ("Explanation of Sheets 187, 195, and 196," p. 59). The road-section mentioned by Jukes is now obliterated and a search made on the site yielded no trace of the boulders. But at Knockakeen Bridge, about a mile to the southward, a boulder of porphyritic granite 10 inches by 8 inches by 6 inches was found. Three miles due east of this locality, some small pieces of porphyritic andesite, which may possibly have come from the igneous rocks of the Limerick district, were also found, along with fragments of flint and chert, and one pebble of porphyritic granite. Mr. Seymour.

Mr. Seymour. The most striking feature of the upland drift is the occurrence of a few isolated mounds of sand and gravel on the highest ground. The position and structure of these mounds seems necessarily to imply the former presence of an ice-sheet covering the whole upland, during the melting of which these mounds were formed.

The largest of these mounds of sand and gravel occurs just outside the north-eastern corner of the map, at an elevation of 590 feet. At Birchhill, three miles north of Carrigtohill, mounds of stratified drift were found at 500 feet above O.D.; and the hill-top about a mile and a half north-west of this place is capped with sand and gravel at 640 feet above O.D., the highest point within the limits of the sheet.

Mr. Muff. The most conspicuous mound of this character within the map occurs at Pigeon Hill, two miles north-west of Birchhill, at a height of about 560 feet, where a mass of steeply cross-bedded and contorted gravel, sand and loam is revealed to a depth of 25 feet in a

Mr. Wright. large pit section. Smaller patches of similar character were found here and there at lower elevations on the undulating upland to the westward for several miles. So far as can be judged from

Mr. Lamplugh. the area surveyed, these high-level mound-gravels tend to form an irregular interrupted chain running approximately east and west along the upland. It was also observed that in the wide intervals between the mounds along this line, the thin covering of loamy drift, which appears to be a modified boulder-clay, and was mapped as such, contained many well-rounded stones. Although no far-transported stones, except chert, were noticed in the open sections of gravel and of this pebbly loam, it is noteworthy that the granite boulders mentioned by Jukes and the far-travelled fragments found on the surface by Mr. Seymour, as above described, occur within the belt of pebbly drift.

Mr. Seymour and Mr. Wright. Patches of glacial gravel also occur here and there within the valleys of the upland, banked against the higher slopes or at the end of the spurs where two streams join; and these gravels are often covered by a few feet of loamy boulder-clay. Gravels of this character were found in several places along the valleys of the Glashaboy and its Riverstown tributary, and were well shown in the excavations for the Queenstown waterworks in a valley north by east of Wakeham's Glen.

Glacial striæ occur very sparingly in the Cork district, but are comparatively more abundant on the northern upland than elsewhere. They indicate a general movement of the ice from west-north-west to east-south-east (see Fig. 5).

The Cork Valley.

Mr. McHenry and Mr. Kilroe. In the Cork valley the drift is often of great thickness and is much more generally prevalent than on the uplands on both sides. It includes many large masses of gravel, and indeed is almost everywhere of a gravelly character, even where technically a "boulder-clay." In the western part of the map it was difficult to decide whether this low-level drift should be

mapped as gravel or as boulder-clay, the bulk of the material being, in fact, a gravel which had been glaciated, re-arranged and mixed with loam so that it shows the compact structureless features of a boulder-clay. Large well-glaciated blocks of limestone are sometimes abundant in this material; and of the smaller stones, part are of limestone and chert, and part of red and yellow grit from the Devonian rocks. Drift of this kind, when screened, yields a large proportion of sand and gravel, and is dug for this purpose in several places south and west of Cork, but it merges gradually into well-defined boulder-clay and cannot be mapped separately from the boulder-clay. Mr. McHe and Mr. Kilroe

Associated with this unstratified drift are many patches of well-stratified sand and gravel, often occurring in the vicinity of craggy outcrops of the solid limestone, and sometimes beneath a covering of a few feet of unstratified stony clay. This stratified drift irregularly lines the limestone-bluffs on the southern side of the River Lee, west of Cork, as far westward as the mapping has been carried, and also occurs in several places among the knolls of limestone east of the city up to the southward bend of the river at Lough Mahon.

The huge mass of stratified drift which chokes up one branch of the valley of a tributary of the Lee at Blackpool, the northern suburb of Cork, attracted the attention of Jukes, and was described in his memoir on the district (p. 59). This mass, which reaches an altitude of 250 feet, consists of strongly cross-bedded sand, gravel and shingle, dipping steeply to the eastward, and arranged in an irregular fan, of which the surface descends gradually eastward, but presents an abrupt slope toward the west. These gravels have been excavated in numerous deep pits, and appear to have a depth, where thickest, of at least 100 feet. The pebbles consist mainly of red, grey, and green grit, with a few much-corroded fragments of limestone toward the base. Thin lenticular bands of stony clay are intercalated with the stratified material in some of the sections. That the deposit is of glacial origin is evident from its position and arrangement, but the exact conditions under which it was accumulated are somewhat problematic. It is probable that it represents the detritus washed from the end of a glacier which filled the westerly branch of the valley when the easterly arm was occupied by a lake held up by the great glacier which filled the Cork valley at this time. Mr. Kilroe.

A striking example of late-glacial and post-glacial erosion has resulted from the blocking up of the lower part of the ancient valley by the above-described mass of gravel. When the general surface-drainage reverted to its original course the waters descending this valley were forced to the southern side of the old hollow, and have there cut a narrow gorge, about 100 feet deep, known as "Goulding's Glen," in the Old Red Sandstone rocks. The present volume of the stream is quite incommensurate with the size of the gorge, and we must suppose that in late-glacial times a much more copious drainage flowed down the valley.

Mr. Wright and Mr. Muff. In the eastward prolongation of the Cork valley, after its abandonment by the River Lee, the prevalent boulder-clay is not quite so gravelly in texture as that farther westward, but the stratified glacial sand and gravel are continued along the depression in increasing quantity. This stratified drift, probably marking the course of the glacial drainage, hangs in an irregular belt along the northern side of Little Island and Foaty Island, and then bends Mr. Seymour. southward, fringing the northern slopes of the tidal channel which separates Great Island from the mainland. In this district coarse shingly gravels, heaped up in irregular mounds and in short ridges with axes ranging predominantly from west to east, cover a belt of ground expanding to a maximum width of a mile, with altitudes rising to about 60 feet. Though interrupted by the transverse channel of the Owennacurra River, this belt of stratified drift is continued eastward to the margin of the map, becoming, however, in this direction, finer in texture. It is well exposed in large sand-pits near Ballynacorra, two miles south of Midleton. The limestone is practically absent from these gravels and also from the boulder-clay of this part of the valley; and although numerous bare crags of limestone rise above the drift-covering, the drift material has been almost entirely derived from the Old Red rocks. It is probable, however, that here, as in other parts of the district, the absence of limestone-detritus may be attributed to its removal in solution by percolating waters.

A further development of stratified drift also occurs along the northern boundary of the valley, north and west of Midleton.

Collective Observations. The limestone beneath the drift, both in the Cork valley and in the Cloyne valley, almost everywhere shows deep fissures and irregular cave-like pits, sometimes two or three feet in breadth, descending as much as 30 to 40 feet from the surface, and filled in with drift like that of the surrounding country, sometimes gravelly and sometimes like boulder-clay. It is probable that most of these cavities were in existence before the drifts were formed, though many have no doubt been since enlarged by percolating waters, and filled up again by the dropping down of loose material from the surface-deposits.

The general arrangement of the drifts in the Cork valley bears out the deduction to be drawn from the glacial striæ which have been observed at a few points within it, and indicates that both the ice-flow and the torrential waters which carried the gravels held their course from west to east along it.

The Central Ridge.

Ir. McHenry Considering the unmistakable evidence that the Central Ridge has been overwhelmed by ice, it is surprising how sparingly the glacial deposits are developed upon it. Rubbly boulder-clay of local origin, and re-arranged drift of indefinite character probably in part rain-wash, are indeed banked rather thickly in places on its lower flanks, especially in the western part of the map; but

on its broad almost flat summit the rock is usually close to the surface, covered only by two or three feet of weathered detritus. There is usually, however, a few feet of red clayey rubble, containing a sprinkling of scratched stones and of transported fragments of chert, in the shallow upland basins at the heads of the streams; and in mapping the ground, this material is not separable from the patches of well-defined boulder-clay which occur in a few places in the deeper hollows. Fragments of flint were found rather abundantly in the cultivated soil, up to an elevation of about 500 feet on the ridge near Lehenagh, but were not observed *in situ* in any of the drift sections. Mr. McHenr

High-level patches of stratified gravel and sand occur in a few places along the northern flank of the ridge, especially in the little glens which open northward into the Cork valley, in the western half of the map. The most striking of these lies at an elevation of 400 feet on the steep slope near Crossnacroha, four miles south-south-west of Cork, and is overlain and in part interstratified with boulder-clay. The anomalous position of these gravels can be explained by supposing that the Cork valley was filled with ice when the heads of the small tributary valleys were comparatively clear and contained temporary ice-dammed lakelets. The presence of a fairly well-marked "dry-gap" or "overflow channel" across a spur of the ridge west of Passage gives support to this interpretation. Mr. Wright.

The most convincing proof of the former glaciation of the ridge is afforded by the presence of numerous transported blocks of a curious brecciated cherty rock on the high ground. These are especially plentiful on Great Island, where blocks ranging up to nine feet in greatest diameter are seen here and there resting on the rock in the fields, and more frequently in the fences and buildings to which they have been artificially removed. Westward, similar boulders were traced in diminished numbers on the summit of the ridge west of the sea-channel, as far as the head of the glen at Rochestown, but none were noticed beyond this place. In the opposite direction they were found sparingly east of East Passage on the hill above Rathcoursey House, close to the boundary of the map. They are also abundant on the ridge of the Southern Anticline south of Aghada, between Cork Harbour and the open coastline, as far eastward as the mapping extended, but were not found on the prolongation of this ridge west of the entrance to Cork Harbour. Mr. Muff.

The source of these blocks has not been determined, nor was any rock of similar character observed *in situ* in the district. But from their area of dispersal, it seems probable that they have been derived from concealed Carboniferous beds assocciated with the limestone in the Cork valley. The absence of limestone boulders on the high ground is remarkable, but the extent to which decalcification has occurred in the gravels, and the extreme corrosion everywhere noticeable on exposed limestone surfaces, render it not improbable Mr. Lamplugh.

that such boulders, if originally present, may have perished by solution. The chert blocks are, of course, excessively durable.

The Cloyne Valley.

Mr. Wright. In the broader portion of this valley, east and west of Cork Harbour, glacial drifts, both stratified and unstratified, are well developed and form a fairly continuous covering, broken here and there by craggy knolls of limestone. The unstratified drift consists mainly of hard boulder-clay—a true "till"— full of well-glaciated blocks of limestone and of detritus from the Lower Carboniferous Shales and Old Red rocks. This boulder-clay is well exposed in cliff-sections south of Ringaskiddy, and where thickest is seen to be divisible into an upper and a lower part, the upper band being more loamy and not nearly so compact as the lower. The division is still further marked by the intercalation of lenticles of sand and gravel in places between the boulder-clays; and it is believed that the thin boulder-clay which overlies the stratified drift in the interior between Ringaskiddy and Carrigaline represents the upper boulder-clay of the cliff-sections. The stratified drift just referred to consists of gravel and sand, forming irregular terraces along the slopes north of the Owenboy River up to its gorge, one mile west of Carrigaline, and also occupying the higher ground between Carrigaline and Ringaskiddy.

Mr McHenry In the upper part of the valley, above the gorge, there are a few isolated patches of sand and gravel, and much rubbly local drift on the hill slopes; but, on the whole, indications of glacial action are much less pronounced than in the more open part of the valley.

Mr. Muff. On the eastern shore of Cork Harbour, sections of boulder-clay similar to those on the opposite shore are exposed in several places. This drift forms a rude terrace along the foot of the steep slope which marks the rise of the Southern Anticline bounding the Cloyne valley. Near Rostellan an irregular moundy ridge of sand and gravel forms the most prominent feature of the glacial deposits, and appears to be prolonged eastward with a winding course in a series of isolated hillocks along the sides of the Saleen estuary up to and beyond the eastern boundary of the map. The esker-like character of this deposit suggests that it represents the sediments of a glacial water-course.

Glacial striæ were observed at several places around Cork Harbour, all indicating an ice-flow approximately from westward to eastward. It is remarkable that the wide north and south gorge which forms the entrance to Cork Harbour has had no influence upon the ice-movement, striæ on the shores of the channel indicating a movement across it, although this opening would appear to be the natural outlet for the Cork Harbour ice.

Southern Anticline.

Mr. McHenry The high ground along the southern edge of the map, so far as the glacial phenomena are concerned, bears much resemblance

to the Central Ridge. Large tracts are practically bare of drift, Mr. McHenr
although masses of clayey local rubble with striated stones occur here and there in the hollows, and are sometimes associated with less ambiguous boulder-clay. The best section occurs at the Ballinphelic Brick and Tile Works, three and three-quarter miles east of Ballinhassig Station, where we find, at an elevation of 250 feet, hard grey boulder-clay, up to 12 feet in thickness, full of local stones and resting on a glaciated rock-surface, with the striæ showing a nearly east-and-west direction of movement. Another part of the brickyard is worked in alluvial grey clay or silt of post-glacial age, accumulated in a hollow which has formerly held a lakelet.

The presence of the boulders of cherty breccia on the high ground Mr. Muff.
east of the Harbour Entrance has already been referred to. These and other confirmatory facts show that the whole ridge has been glaciated.

At Crosshaven a thick mass of stratified gravel and sand, seen Mr. Wright
to a depth of 30 feet in a pit section, is banked up in an embayment of the northern slope in the same way that similar deposits are banked against the corresponding slope of the Central Ridge.

The pre-glacial shore along the southern or outer side of the Mr. Muff.
ridge has been previously described. The accumulation of local rubble or "head" above this shore attains a thickness of 35 feet in the cliff-sections below Trabolgan House. This "head" has been accumulated partly before the glaciation of the district, and partly afterwards, as a band of boulder-clay often occurs near the top of the rubble.

An examination of the coast-sections to the eastward of the present map reveals a striking difference between the glacial deposits east and west of Power Head. The thick accumulation of drift in the deeper bays to the eastward consists in the lower part of a stiff bluish marly boulder-clay very different from any boulder-clay seen to the westward of Power Head. This boulder-clay contains relatively few stones, but many of those which do occur are of distant origin, including granites, porphyries, andesitic breccias, flints, etc., along with a sprinkling of fragments of marine shells. This clay is evidently the prolongation of that which lines the eastern coast of Wicklow and Wexford, recognised as the product of the ice-sheet which filled the basin of the Irish Sea. In some of the County Cork sections it is overlain by a few feet of red rubbly boulder-clay full of the Cork rocks, of similar character to the prevalent drift of the country to the westward.

This eastern boulder-clay is well developed in Ballycroneen Bay, only a half-mile east of the limits of the present sheet, there overlapping the pre-glacial shore; but it was not found at any point to the westward, though it may possibly occur just within the map in the nterior, where, however, there are no open sections.

A moundy mass of sand and gravel which covers the hill-top north of Power Head, at the extreme south-eastern corner of the

map, may be associated with the eastern drift and may indicate its stream-washed margin, as the gravel contains abundant flints along with pebbles of granite, felsite, and quartz-porphyry.

. Lamgh. The presence of this eastern drift suggests an explanation for the anomalous direction of glaciation of the country within the map. The outflow from the "West British Ice-sheet" occupying the basin of the Irish Sea appears to have gone westward and south-westward along the sea-floor bordering County Cork for some distance to the west of Cork Harbour, and thus to have prevented the ice of the interior from passing along the natural drainage channels southward. The cliff-sections south of Youghal indicate that the two sheets were contemporaneous and confluent, but that the eastern mass shrank back while the western ice was still advancing.

LATE-GLACIAL AND POST-GLACIAL DRAINAGE CHANNELS.

Although no radical changes in the drainage system of the district have taken place since pre-glacial times—the drift deposits being of insufficient thickness to bring about such alterations as those found in the Dublin and Belfast areas—there are yet numerous minor alterations due to the glaciation which are of considerable interest from the light which they throw upon the mode of origin of the drifts and the relative length of the time-interval since the glacial episode.

. Seymour. The deep trenching of the edges of the uplands, which, as previously stated, had been in progress for some time before the glaciation, must have been arrested when the main strike-valleys were filled with ice, but was renewed with great vigour as soon as the channels were re-opened by the recession of the ice. The great fans of gravel which are spread out on the floor of the wide strike-valleys at the mouths of the transverse gorges in both the Cork and the Cloyne valleys are probably relics of the floods which marked the re-establishment of the land-drainage.

McHenry, Wright, Muff. In the western part of the map there are several instances in which small streams have been locally diverted from their pre-glacial channels. In such cases, instead of the regular unbroken gradient of the older parts of the valleys, we find the stream running in a rock-bound channel, sometimes interrupted by small waterfalls.

Seymour. An interesting example of glacial stream-diversion occurs on the northern upland near Leamlara, five miles N.W. of Midleton, where a short rocky gorge known as Tattan's Gorse, which forms a connecting loop between two older valleys, has been excavated into the slope of a gently rounded hill, in a position inexplicable except under the hypothesis that the neighbouring valleys were blocked with ice. Several less conspicuous examples of similar character were observed in the ground to the westward.

Wright. Somewhat different is the case of the fine rock-gorge on the Glashaboy River between Glanmire and Riverstown. Here the pre-glacial valley has been blocked by a thick deposit of gravel,

and the river has been forced to the eastern side of its old channel, cutting a trench 300 yards long and 60 to 70 feet deep in the solid rock. It is noteworthy that the stream has had time to grade down this new segment of its course to the general level and that there is no waterfall in the gorge. Mr. Wright.

The gorge at Goulding's Glen, near Cork, previously described, has been excavated under similar conditions, but is more striking on account of the much smaller volume of water now passing through the glen. Mr. Kil oe.

The glacial and post-glacial erosion-phenomena prove that land-conditions only can have prevailed during and since the later stages of the Glacial Period. The character of the drifts indicates that although the district was covered with land-ice, the covering was not nearly so deep as that of the Dublin and Belfast areas, and that it was of shorter duration; and this conclusion is sustained by the strongly marked effects of erosion since the glaciation. Mr. Lamplugh.

POST-GLACIAL DEPOSITS.

An extensive tract of alluvium occurs in the Cork valley along the course of the River Lee. The higher terraces consist of flood-gravel and the lower of silty loam. At Cork the rock-floor of the valley, from the evidence yielded by borings, appears in the deeper part to be at least 90 feet below Ordnance Datum. The material filling this buried channel is described as consisting chiefly of "rough gravel," "boulders" and "fine gravel," with beds of peat in the upper part. It is possible that the whole of the gravel may be a post-glacial river-gravel, which would indicate an elevation of the land during the early part of post-glacial times to not less than 100 feet above its present level. Even supposing that the lower part of the gravel is a glacial deposit (the evidence being inconclusive on this point), it is at least certain that the peat-beds and all the overlying sediments are post-glacial, and there must have been some degree of post-glacial elevation for these beds to have been accumulated in their present position. This matter will be fully discussed in the forthcoming memoir, where also a detailed account will be given of the great changes which have taken place in the Cork estuary within historic times owing to the growth of the city, the reclamation of the tidal flats, and other artificial works. Similar reclamation has been carried on at numerous places along the broad foreshores of the ramifying system of shallow tidal waters draining into Cork Harbour. Mr. Kilroe.

Another broad tract of recent alluvium occupies the low ground at the foot of the northern slope of the Central Ridge from Douglas westward. A similar tract at the foot of the same slope in the western part of the map, separated by a low barrier from the Douglas basin, appears to be of considerable antiquity, being mainly composed of the coarse detritus swept down by the little streams from the uplands at a time when their floods were far stronger than at present. Mr. McHenry

Mr. Seymour. A narrow shelf barely above present high-water level of spring-tides, occurring along the northern shore of the tidal channel which separates Great Island from the mainland and also along some of the inlets entering Cork Harbour south of Great Island, may possibly represent a slight post-glacial depression, though the difference of level cannot have exceeded five feet and the evidence is somewhat indefinite. The Post-Glacial Raised Beach which was so distinctly marked along the shores near Dublin and Belfast is not represented in the Cork district, unless by this obscure and scarcely elevated shelf. On this shelf at several places between Foaty Island and the Owennacurra estuary, oyster-shells, along with a few shells of other edible molluscs, are piled up in immense quantities, the thickness of the mass in one place, west of Brown Island, being as much as six feet, and covering an area estimated at about seven acres. The origin of these shell-heaps, which are believed to be artificial ("kitchen-midden") deposits has been much discussed by the local archæologists.

ECONOMICS.

There are no mines or metalliferous deposits within the area of this map. The Carboniferous Limestone is very extensively quarried both as a building stone and for lime-burning. The red-stained beds of limestone also furnish a handsome ornamental marble when polished, the principal quarries for this stone being those near Midleton.

The public water-supply for the city of Cork is obtained from the river-gravels in the Lee Valley west of the city, by means of an infiltration tunnel. The smaller towns which have an organised supply obtain the water from reservoirs on the upland streams, supplemented in the case of Queenstown by the outflow from local springs.

IV.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year:—

A. ENGLAND AND WALES.

I.—MAPS.

One-inch Maps (New Series.)

London district in four Sheets; Drift, colour-printed.
With additions by T. I. Pocock and J. A. Howe.

156 (Leicester). Solid, hand-coloured; Drift, colour-printed.
By C. Fox-Strangways.

298 (Salisbury) Drift, colour-printed.
By C. Reid, F. J. Bennett, and A. J. Jukes-Browne.

317 (Chichester) Drift, colour-printed.
By C. Reid, G. W. Lamplugh, and C. E. Hawkins.

The following maps previously issued hand-coloured, have been replaced by colour-printed maps :—

231 (Merthyr Tydfi) Drift and Solid.
232 (Abergavenny), Drift.
248 (Pontypridd), Drift.
261-2 (Bridgend), Solid and Drift.
263 (Cardiff), Solid and Drift.
330 (Lymington and Cowes), Drift.
331 (Portsmouth), Drift.
Isle of Wight, Special Map, Drift.

Six-inch Maps.

STAFFORDSHIRE.

3 S.W. Congleton.
3 S.E. Rushton James.
6 N.E. Moreton.
6 S.W. Alsagar.
6 S.E. Kidsgrove.
7 N.W. Bradley Green.
7 N.E. Horton.
7 S.W. Brindley Ford.
7 S.E. Endon.
11 N.W. Audley.
11 N.E. Tunstall.
11 S.W. Halmer End.
11 S.E. Chesterton.
12 N.W. Smallthorne.
12 N.E. Bagnall.
12 S.W. Hanley.
12 S.E. Wetley Moor
13 S.W. Consall.
13 S.E. Ipstones.
16 N.E. Checkley.
16 S.E. Woore.
17 N.W. Madeley.
17 N.E. Newcastle-under-Lyme.
17 S.W. Whitmore.
17 S.E. Clayton.
18 N.W. Stoke-on-Trent.
18 N.E. Caverswall.
18 S.W. Trentham.
18 S.E. Longton.
19 S.E. Cheadle.
22 N.E. Mucklestone.
23 N.W. Maer.
23 N.E. Beech.
24 N.W. Barlaston
24 N.E. Fulford.

Six-inch Reference Maps.

Twenty-two MS. coloured copies of six-inch quarter sheets have been made from the field copies and deposited in the office for for public reference. These are as follows :—

Carmarthenshire.—41 N.E., S.W. ; 42 N.W. ; 48 N.E., S.E. ; 54 N.E. ; 55 N.W., S.W. ; 57 N.W. ; 58 N.E., S.E.
Devonshire.—108 S E
Glamorganshire.—7 N.E. ; 14 N.W., S.W. ; 22 S.E. ; 23 S.W., S.E. ; 31 N.E., S.E. ; 32 N.W., N.E.

II.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom for 1902, pp. 240. Price 1s.

The Cretaceous Rocks of Britain. Vol. II. The Lower and Middle Chalk of England. By A. J. JUKES-BROWNE, with contributions by W. HILL, pp. 568. Price 10s.

The Geology of the Isle of Man. By G. W. LAMPLUGH, pp. 620. Price 12s.

The Economic Geology of the Isle of Man (reprinted from the Geology of the Isle of Man), pp. 184. Price 1s. 6d.

Index to "Report on the Geology of Cornwall, Devon, and West Somerset." Compiled by C. REID, pp. 33. Price 1s.

The Geology of the South Wales Coal Field, Part IV. (the country around Pontypridd and Maes-teg). By A. STRAHAN, R. H. TIDDEMAN, and W. GIBSON, pp. 134. Price 1s. 6d.

The Geology of the Cheadle Coal Field. By G. BARROW, pp. 62. Price 2s.

The Geology of the Country around Leicester. By C. FOX-STRANGWAYS, pp. 122. Price 3s.

The Geology of the Country around Reading. By the late J. H. BLAKE. Edited by H. W. MONCKTON, pp. 91. Price 1s. 6d.

The Geology of the Country around Salisbury. By C. REID, with contributions by H. B. WOODWARD, F. J. BENNETT, and A. J. JUKES-BROWNE, pp. 77. Price 1s. 3d.

The Geology of the Country around Chichester By. C. REID, with contributions by G. W. LAMPLUGH and A. J. JUKES-BROWNE, pp. 52. Price 1s.

The Geology of the Country around Torquay. By W. A. E. USSHER, pp. 142. Price 2s.

B. SCOTLAND.

I.—MAPS.

Six-inch Reference Maps.

Duplicates of Six-inch Maps.

The following manuscript copies of six-inch sheets have been made from the field copies and deposited in the Office for public reference :—

Argyllshire. 9, 10, 19, 20, 30, 87, 90, 99, 111, 121, 122, 123, 128, 129, 136, 137, 138, 147, 148, 149, 157, 158, 159, 160.
Fifeshire. 39.
Inverness-shire. 28, 101.
Perthshire. 29, 41, 50.
Ross-shire. 18, 23.

II.—MEMOIRS.

The Geology of North Arran, South Bute and the Cumbraes. By Sir A. GEIKIE, B. N. PEACH, W. GUNN, and A. HARKER. pp. 200. Price 4s.

Summary of Progress (*noted under England*).

C. IRELAND.

I.—MAPS.

One-inch Maps.

Publications in 1903.

[Sheet 112, Dublin (Drift edition), colour-printed, dated 1902.]

Six-inch Reference Maps.

The undermentioned Sheets of the Belfast District, have been copied from the field maps of the Drift Survey, and are now available for reference at the Dublin Office :—

Co. Antrim. 56, 57, 60, 61, 64, 65, 68.
Co. Down. 1, 4, 5, 8, 9, 10, also 2, 6, 11, 14, 15, 16, 17 as far as completed.

Also a special Municipal six-inch map of Belfast, including both the Antrim and Down parts of the city.

II.—Memoirs.

The Geology of the Country around Dublin. By G. W. Lamplugh, J. R. Kilroe, A. McHenry, H. J. Seymour, and W. B. Wright, pp. 160. Price 3s.

Summary of Progress (*noted under England*).

LIST OF EXTRA OFFICIAL PUBLICATIONS.

Anderson, Dr. T., and Flett, Dr. J. S.—Report on the Eruptions of the Soufriere, in St. Vincent, in 1902, and on A Visit to Montagne Pelée in Martinique. Part I. *Phil. Trans. Royal Soc.* Series A, vol. 200., pp. 353-553, plates 21-39.

Clark, R.—Notes on the Fossils of the Silurian Area of N.E. Ireland. *Rep. Brit. Assoc.* for 1902, p. 599.

Clough, C. T.—The disappearance of Limestones in High Teesdale. *Geol. Mag.* Dec. iv., vol. x., pp. 259-262.

Gibson, W., C. B. Wedd, and others. Excursion to North Staffordshire. *Proc. Geol. Assoc.*, vol. xviii., 1903, pp. 173-184.

Harker, A. Granite and Quartz Veins. *Geol. Mag.*. Dec. iv., vol. x., p. 95.

————The overthrust Torridonian Rocks of the Isle of Rum, and the Associated Gneisses. *Quart. Journ. Geol. Soc.*, vol. lix., pp. 189-215, pl. xiv.

Howe, J. A.—Excursion to Denham and Gerrards Cross, to the cutting on the Great Western Railway. *Proc. Geol. Assoc.*, vol. xviii., pp. 189-190.

————The Economic and Hygienic Aspect of Waters from the Carboniferous Limestones of Britain. *XI^e. Congrès Internat. d'Hygiene et de Démographie, Bruxelles.*

Kilroe, J. R.—Table of Strata, with notes on Economic Minerals and Stones, as well as upon Soils and Subsoils, to serve as a general explanation of, and to accompany the one-inch published geological sheets of the map of Ireland. *Dublin.*

Kitchin, F. L. The Jurassic Fauna of Cutch, vol iii., Part ii, No. 1. genus Trigonia, pp. 1–122, plates i–x, 1903. *Palæontologia Indica*, Series ix.

Lamplugh, G. W.—Land shells in the Infra-Glacial Chalk Rubble at Sewerby, near Bridlington. *Geol. Mag.*, Dec. iv., vol. x., p. 513.

————On the Disturbance of Junction Beds from Differential Shrinkage and Similar Local Causes during Consolidation. *Geol. Mag.*, Dec. iv., vol. x., p. 516.

————Belemnites of the Faringdon Sponge Gravels. *Geol. Mag.*, Dec. iv., vol. x., pp. 32–34.

————and J. F. Walker.—On a Fossiliferous Band at the top of the Lower Greensand near Leighton Buzzard. *Quart. Journ. Geol. Soc.*, vol. lix., pp. 234–264.

McHenry, Alexander. Report on the Ox Mountain Rocks and their probable continuation from Galway and Mayo into Donegal, Tyrone and Londonderry. *Proc. Roy. Irish Acad.*, vol. xxiv., Sect. B., Pt. iv.

MUFF, H. B., and W. B. WRIGHT. On a pre-Glacial or Early Glacial Raised Beach in County Cork. *Geol. Mag.*, Dec. iv., vol. x., p. 501.

NEWTON, E. T. Report upon the Birds' Bones found in the Caves of Keoh, County Sligo. See Report of the Exploration, by Dr. R. F. Scharff and others. *Trans. Roy. Irish Acad.*, vol. xxxii., p. 184.

————Note upon the Bones found during Excavations on the Site of the Roman City of Silchester, Hants, in 1892. (See Report by W. H. St. J. Hope). *Archæologia*, vol. lviii., 1903.

PEACH, B. N., and J. HORNE.—The Canonbie Coalfield: its Geological Structure and Relations to the Carboniferous Rocks of the North of England and Central Scotland. *Trans. Roy. Soc. Edin.*, vol. xl., pp. 835–877, plates 1–4.

POCOCK, T. I.—Excursion to Grays. *Proc. Geol. Assoc.*, vol. xviii., pp. 143–144.

SCRIVENOR, J. B.—The Granite and Greisen of Cligga Head (Western Cornwall). *Quart. Journ. Geol. Soc.*, vol lix., pp. 142–159.

————Notes on the Geology of Patagonia. *Ibid.*, pp. 160–179.

————(1) Anatase in the Trias of the Midlands of England. (2) A Peculiar Occurrence of Magnetite in the Upper Bunter Sands. *Min. Mag.*, vol xiii., pp. 348–352.

SEYMOUR, Henry J.—A Preliminary List of the Minerals occurring in Ireland. *Rep. Brit. Assoc.* for 1903, p. 598.

SHERLOCK, R. L.—The Foraminifera and other Organisms in the Raised Reefs of Fiji. *Bull. Mus. Comp. Zool. Harvard Coll.*, vol. xxxviii.

TEALL, J. J. H.—On Dedolomitisation. *Geol. Mag.*, Dec. iv., vol. x., 513.

WOODWARD, H. B.—On some Disturbances in the Chalk near Royston (Hertfordshire). *Quart. Journ. Geol. Soc.*, vol. lix., pp. 362–374.

————Excursion to Royston, Hertfordshire. *Proc. Geol. Assoc.*, vol. xviii., pp. 166–170.

————The Jurassic Limestones of Great Britain. *XI^e Congrès Internat. d'Hygiene et de Démographie, Bruxelles.*

APPENDIX.

I. THE GEOLOGICAL SURVEY IN REFERENCE TO AGRICULTURE: WITH REPORT ON THE SOILS AND SUBSOILS OF THE ROTHAMSTED ESTATE.

BY HORACE B. WOODWARD, F.R.S.

The benefit that might be derived from a knowledge of Geology, in appraising the capabilities of the land, was recognised more than a century ago by the old Board of Agriculture, and they published in their valuable and interesting Reports (1794–1813) some of the earliest geological sketch-maps of the English counties.

When therefore the Geological Survey commenced its labours on the one-inch map, it was natural to anticipate "the great advantages which must accrue from such an undertaking, not only as calculated to promote geological science, which would alone be

a sufficient object, but also as a work of great practical utility, bearing on agriculture, mining, road-making, the formation of canals and rail-roads, and other branches of national industry.*

De la Beche, in his "Report on the Geology of Cornwall, Devon and West Somerset," devoted seventeen pages to the "Agriculture" of the extensive and varied district which had then been geologically surveyed, pointing out the connection between the rocks exposed at the surface and the striking contrasts in the productive characters of the soil, and remarking "that if the scale of the map be sufficiently large, the relative fertility may in some cases be traced even across fields, portions of them being far more productive than others."†

The Geological Survey had begun work in a district where the ordinary stratified and igneous rocks come to the surface without the great coverings of Drift that are elsewhere met with—the alluvial deposits in the valleys and the blown sands along the coast being the only superficial deposits of any extent.

Thus, as remarked by Murchison in 1865, "In the earlier years the Geological Survey was limited to the delineation of the outline of the several rock formations which constitute the true subsoil of each district. But, as in many of the tracts which had to be surveyed, such rock or subsoil is frequently not to be seen at or near the surface, over considerable spaces, which are covered by thick masses of sand and clay, and broken and drifted materials of other rocks, thus concealing the true subsoil, I deemed it to be essential, to render the National Geological Survey as valuable to agriculturists as it is to miners, to map these surface drifts." ‡

Hence arose the distinction between the published maps; some show only the "SOLID" geology or the distribution at or near the surface of the igneous and stratified formations irrespective of the Drift deposits; others called the "DRIFT" maps show the solid rocks where they are exposed, and also the various superficial deposits or drifts that are elsewhere spread over the area.

At first these "surface drifts" were undivided, being represented on the maps as one accumulation; and an example of this survey is shown on the old series map, Sheet 45 N.E.

It soon became apparent that this rough and ready style of mapping the "Drift" would not meet the requirements of agriculturists or of others interested in the surface geology. It was necessary to sub-divide the drifts into boulder-clay, sand and gravel, brickearth or loam, and this method of mapping was carried out in the Eastern counties and subsequently elsewhere.§

Not, however, until the Ordnance Survey had issued six-inch maps of all the counties in England and Wales, was it possible to

* Address to Geological Society, 1836, by C. Lyell, *Proc. Geol. Soc.*, ii., 358.

† Report, 1839, p. 463.

‡ Annual Report of the Director-General of the Geological Survey for 1865.

§ See H. B. Woodward, The Soils and Subsoils of Norfolk, *Trans. Norfolk Nat. Soc.*, Vol. vii., p. 401.

represent clearly and in sufficient detail for practical purposes, the distribution of the various superficial deposits. This is now done in all cases, and MS. copies of the six-inch geological maps are deposited in the Office for public reference.

These maps show the actual distribution of the several igneous and stratified rocks, as well as the less regularly disposed coverings of drift—all may be of importance where they come to the surface, in their bearings on agriculture or sanitary engineering, and all under these circumstances are strictly to be regarded as *sub-soils*.

The Geological Survey maps are thus SUB-SOIL MAPS.

It is true that the term "sub-soil" is sometimes restricted to the broken up and weathered portion of a rocky substratum, as in the case of a tract of oolitic limestone. There the solid rock would merge upwards into the "sub-soil"—a rubble of weathered rock and reddish-brown loam, and this sub-soil would be covered by six or eight inches or more of greyish-brown brashy soil. In this case, however, the sub-soil would be represented as a part of the substratum, and so coloured on the Geological Survey map.

In many other cases where an area is formed of Chalk, or London Clay, or Keuper Marl, the formation may occur directly beneath a thin soil, with no intermediate broken rock or "sub-soil," and no other signs of weathering than the alteration in some cases of a blue clay into brown clay.

In the same way the various Drift deposits constitute true subsoils; they may attain a thickness of 50 or 100 feet, or more, and they occur directly beneath a variable coating of soil. Whether therefore the soils rest directly on a mass of weathered rock or on a solid formation of clay or other kind of formation, the Drift Maps of the Geological Survey are intended to represent what is immediately beneath the soil.

The question which then arises is, How far can sub-soil maps be taken as an indication of soils? The answer is that the maps can only be interpreted with knowledge and judgment. They should be invaluable with reference to sub-soil water and drainage, but they cannot be taken as indicating in more than a general way, the actual distribution of soils.

If the soil were invariably "sedentary" then the Geological Survey Maps would be direct guides to its character. But while due mainly to the disintegration of the subsoil, to the decay of animal and vegetable matter, to adventitious wind-drifted material, and to the organic agents constantly at work in the surface layers, the soil is liable in many localities to displacement, or removal from higher to lower levels; so that soils derived mainly from one formation are transferred in part to the surface of another. The geological boundaries are drawn on the maps to correspond as nearly as possible with the natural and superficial limits of each formation (solid and drift); but they take little or no heed of the effects of downwash, landslipping, etc.

Not only soils, but sub-soils are thus displaced. The debris from plateau deposits may be thickly strewn along the foot of slopes below scarps; and where much gravel has been thus dislodged, it may be that gravel-pits have been opened in it. Our maps at present fail in depicting such accumulations, but these should be mapped wherever possible.

There are other cases where masses of clay have slipped over portions of the same clay-formation, and in this way bones of Hippopotamus have been entombed in London Clay, and of Elephant in Kimeridge Clay! In these instances it would not have been possible to separate the slipped or re-deposited clay from the undisturbed formation; and from an agricultural point of view this would be of no consequence.

A downwash of soil from the hills or higher grounds is almost invariably met with on slopes and in vales; and mixed soils, and soils of considerable depth are to be expected in particular situations according to the natural features of the land. The fertility of low-lying clay-lands is often conspicuously improved by these downwashes.

In interpreting the Geological maps, attention must not only be given to these matters, it must also be paid to the lithological characters of the formations. Some are fairly uniform masses of clay of wide extent and great thickness, like the Keuper Marls, the Oxford and Kimeridge Clays, the Gault, and the London Clay. Others, like the Forest Marble, the Corallian, the Reading Beds, the Clay-with-flints and other Drift accumulations, may be of very inconstant character, made up of sands, clays and limestones, or of sands and pebble-beds and clays alternating, or of deposits confusedly arranged.

There are frequent cases where a geological formation tapers away through denudation, so that but a remnant remains in corporated with the soil. Thus a thin gravelly or sandy soil may occur on a clay sub-soil; the map showing only clay, and affording no indication of the nature of the soil. Here notes on the maps should supply the information.

The system suggested in 1850 by Joshua Trimmer, who was then attached to the Geological Survey, has been followed in some of the German agricultural maps. He introduced a notation to indicate the character and depth of soils and sub-soils.* Thus the symbols—

$$\begin{array}{r} gl\ 10'' \\ \hline g\ 2' \\ \hline c\ 4'+ \end{array}$$

would indicate ten inches of gravelly loam over two feet of gravel, with clay below proved to depth of four feet.

* "Proposals for a Geological Survey, specially directed to Agricultural Objects." 8vo, London.

An indication of the thickness of soil, and also of the sub-soil, should be given on the maps, where precise information has been obtained.

The utility of the six-inch Geological Survey maps, as at present prepared, has been recognised by Mr. Douglas A. Gilchrist (formerly Director of the Agricultural Department of Reading College), in his Reports on the soils of Dorset; and Mr. A. D. Hall (formerly Principal of the South-Eastern Agricultural College) observes that "in the main, geological origin may be taken as the basis of a soil survey." If the data suggested could be added to the maps there is no doubt that they would be of the greatest service, that is possible from a geological point of view, to the agriculturist.

A map of the soils alone would give a very imperfect idea of the capabilities of the land, as it would fail to indicate the structure of the ground, and the pervious or impervious nature of the sub-soil. Moreover as soils merge laterally, it would be far more difficult to draw any definite geological lines to separate them, than it is to draw lines separating the sub-soils, which, whether in uniform or variable masses, overlie one another.

The general character of the soils is however to be inferred from the map of the sub-soils, by those who are acquainted with the local characters of the geological formations and with the physical features of the land. When the country is in possession of a complete series of "drift" maps on the scale of six inches to the mile, then, as Mr. Hall has remarked, "the work could be rapidly supplemented by soil surveys and analyses executed by the local agricultural colleges and research institutions, until every farmer could be put in possession of that exact knowledge of the soil which is fundamental to all farming operations."*

With the view to ascertain how far it was practicable to make a geological map of the soils of an estate, the writer was deputed to visit the experimental Farm at Rothamsted and to note as far as possible the relations of soils and subsoils on the six-inch map.

THE SOILS AND SUB-SOILS OF THE ROTHAMSTED ESTATE.

The old Manor-house of Rothamsted is situated about a mile to the south-west of Harpenden Station in Hertfordshire. The experimental farm was founded by Sir John Bennet Lawes, the owner of Rothamsted, who as early as 1843 gave up certain plots of ground for special cultivation. From that date and for upwards of fifty years, he was aided in his researches by Dr. (afterwards Sir) J. Henry Gilbert. Since the death of Sir John Lawes and of his associate, the work has been carried on by the Lawes Agricultural Trust, and Mr. A. D. Hall is now the Director.

* "The Soil," by A. D. Hall, 1903, pp. 265, 271.

The main object has been to study the influence of various manures on crops of wheat, barley, roots, grasses. etc. The particular fields which are noted on the accompanying map, are as follows :—

Park Grass — *Permanent grass land.*
Broadbalk — *Wheat.*
Hoos Field — *Barley, leguminous crops, etc.*
Barn Field — *Roots.*
Agdell Field—*Four-course rotation.*

The accompanying map, a portion of the six-inch Ordnance sheets, is shaded to show the distribution of the subsoils and soils as follows :—

Sub-soils.	*Soils.*
5. VALLEY GRAVEL.	5. Loamy and gravelly soil.
2, 3, 4. CLAY-WITH-FLINTS (mixed subsoil of stiff reddish-brown and mottled clay with flints, also loam, sands and pebble-gravel.)	4. Soil loamy with few stones. 3. Mixed heavy soil—more or less stony. 2. Mixed lighter soil—more or less stony.
1. CHALK.	1. Soil; downwash of light loamy and gravelly soil.

The geology of the Rothamsted estate is comparatively simple. Chalk forms the foundation of the entire area, but it is exposed only on the slopes. The plateau ground is covered with a very mixed deposit of Clay-with-flints, with remnants of the mottled clays, sands and pebble-beds of the Reading series, and also remnants of Drift gravel. The low grounds are occupied by Valley gravel.

The Experimental Fields belonging to the Lawes Agricultural Trust are entirely on the mixed deposit of Clay-with-flints, etc.

The nature of this accumulation is well seen in the brickyard south of Hatching Green on the south-east of Rothamsted Hall; also in a "gravel pit" south-west of Round Wood (Fig. 7), and in an "Old Chalk Pit" north of Moreton End (Figs. 8 and 9.), nearly one mile to the north-west of the Midland railway station at Harpenden.

In these pits we find almost every variety of sedimentary deposit. The Chalk, which is extensively "piped," appears here and there in irregular pinnacles near the surface. It is usually lined with stiff red or dark brown clay-with-flints, the joints in the clay, and also the flints, being blackened by manganese-oxide. Masses of this stiff clay-with-flints form the sub-soil in places; elsewhere light sands or red loamy sands with or without black flint pebbles, or masses of pebbles alone, form the immediate subsoil; again, grey or mottled clay or loam with occasional pebbles or free from stones, or with a gravelly pocket here and there, extends for some distance, immediately beneath the soil. These accumulations occur in irregular juxtaposition owing to the piped surface of the Chalk, and in places there is a kind of marl (Fig. 9) formed on the slopes by the weathered rubbly chalk mixed with earth.

Covering these subsoils there is a soil of grey flinty or pebbly loam, 10 inches or more in thickness, and varying in character

according to the number of stones in it; in some cases rough and unworn flints prevail, elsewhere there is an admixture of pebbles, and over some areas the soil consists of loam with comparatively few stones. In all cases excepting on the Chalk slopes and in the valley bottom, the soil is to be regarded as a heavy mixed soil, for

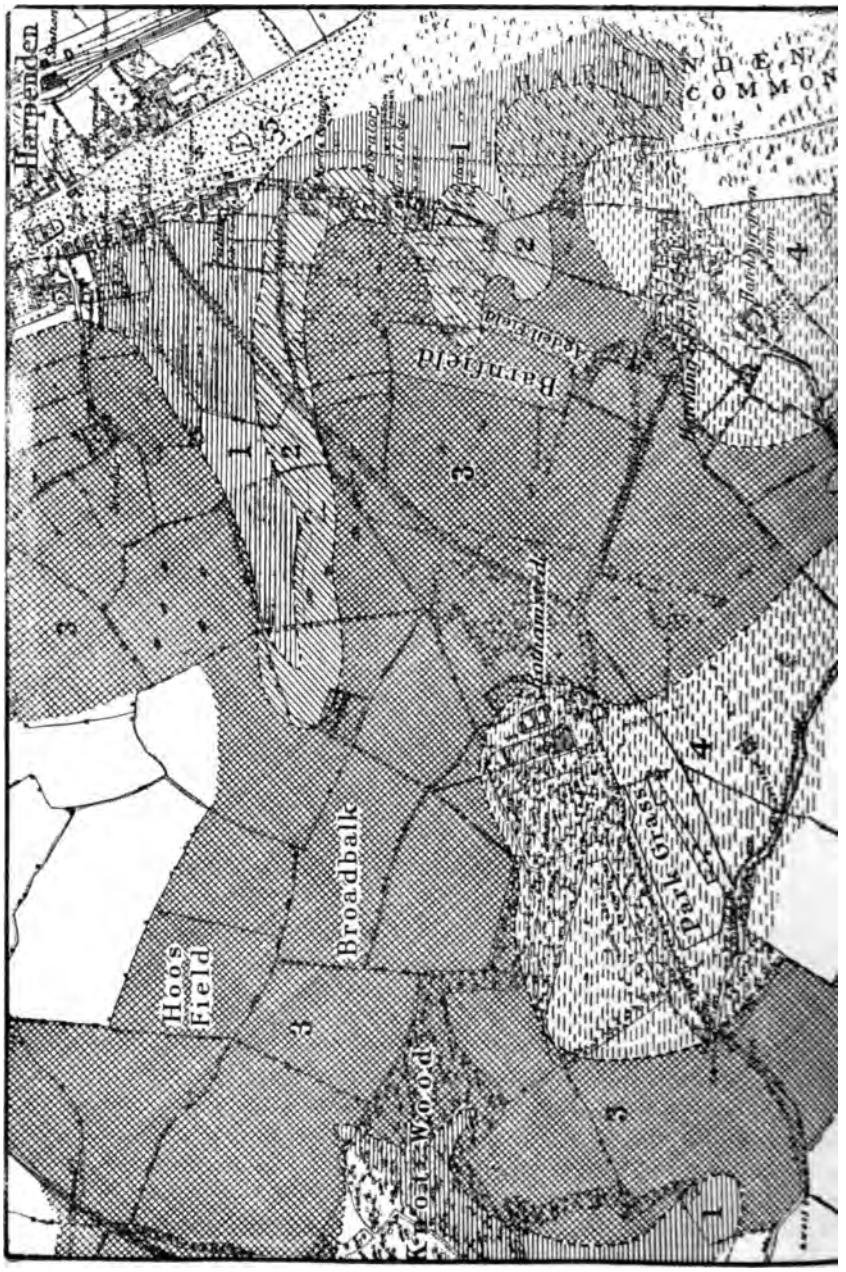


FIG. 6.—*Map of Rothamsted, near Harpenden.*

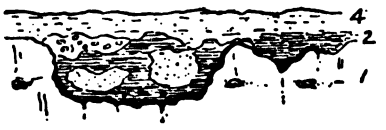
the sub-soil is in the main a heavy clay; and were it not for the fact that the Chalk here and there approaches very near to the surface of the higher grounds, the land would be much wetter after rain than is the case. These underground pinnacles of Chalk, and the pockets of sand and gravel, act as dumb-wells for the surface drainage.

FIG. 7.—*Section S.W. of Round Wood, N.W. of Harpenden.*

4. Grey flinty loam. | 2. Clay-with-flints.
3. Gravel. | 1. Chalk-with-flints.

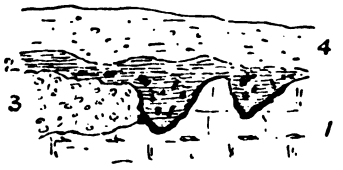
Thickness seen about 10 feet.

FIGS. 8 & 9.—*Sections in "Old Chalk pit" north of Moreton End, Harpenden.*



4. Grey stony loam.
2. Red Clay-with-flints, with galls of sand, and overlying chalky gravel,
1. Chalk-with-flints.

Thickness seen about 3 feet.



4. Brown stony loam.
3. Weathered rubbly and earthy Chalk.
2. Brown and dark red Clay-with-flints.
1. Chalk-with-flints.

} about 5 feet.

Taken as a whole the soil on the uplands, and over the whole of the experimental farm, while it varies in depth, does not vary sufficiently in character to indicate the precise positions of the larger underlying pockets of sand or gravel. The porosity of particular tracts, where it is known that adventitious causes have exerted no influence, may perhaps be indicated by the character of the crops.

Here and there ploughing has turned up red clay (or clay-with-flints) as in the northern part of Hoos Field, it has been dug up in the allotments, and exposed in a trench east of Broadbalk; and in instances where the soil is full of rough unworn flints, there is no doubt that the subsoil is mainly the stiff clay-with-flints. This is represented by the darker cross-shading (3) on the map.

On the borders of the gentle slopes where the Chalk comes near to the surface, the soil is lighter and probably somewhat deeper, as in those places indicated on the map by oblique shading (2).

To the west of Rothamsted, near the Ice-house; and southwards over the "Park Grass," at Hatching Green, and around the brickworks, the prevailing character of the subsoil is a clay or sandy clay (brick-earth) with few stones. These areas, which can only be roughly separated, are marked on the map by broken-lines (4).

Judging from the geological evidence the conclusion would be that the plateau ground occupied by the Clay-with-flints (2, 3 and 4) must be treated from one general point of view, based on the fact that the sub-soil is for the most part heavy. The results of analyses here and there of lighter portions of the soil or sub-soils would hardly throw light on the general agricultural capabilities of the fields, which would be more affected by aspect and shelter than by other physical conditions. If analyses be made from the mixture, say of a dozen samples, of soil taken from different parts of one field, the best indication of its agricultural value from a chemical and mechanical point of view would then be obtained.

[Mr. Hall informs me (Aug. 1904) that the results of recent mechanical analyses of the Rothamsted soils, taken from the different experimental fields, show that "Complex as the Rothamsted subsoil certainly is, it is not too much to say that a single analysis from any part of the land would show the type of soil to be dealt with over the whole area." See his paper on "The Mechanical Analysis of Soils," *Trans. Chem. Soc.* vol. lxxxv., p. 950, (1904).]

II. First Notes on the Petrography of Western Cornwall.

BY JOHN S. FLETT, M.A., D.SC., F.G.S.

A few of the more important results arising from the investigation of Cornish rocks during the past year may here be mentioned, though it is not intended to forestall the fuller information which will ultimately be embodied in the memoirs.

The Sediments.—The sedimentary rocks which form the groundwork of the country have not yielded many points of novelty, except where they have been altered by the intrusive igneous masses. The fine dark grey shales which adjoin the Land's End granite are often intensely crumpled and have partly been converted into phyllites where the movement has been most intense. Their silky lustre indicates the large development of new micas, principally a colourless muscovite; and though their cleavage is imperfect in the hand specimen, they often show a well-developed ausweichungsclivage under the microscope. The quartzoze grits associated with them are, as a rule, less altered. In many of them, particularly in the eastern part of Cornwall, the clastic characters are very perfect; the rocks, in fact, are fairly typical greywackes. In the west they are more sheared, and often infiltrated with secondary quartz. Occasionally a mylonitic band is encountered in which the clastic pebbles have been converted into fine granulitic

powder, and the development of cataclastic structures can be traced stage by stage as the quartz pebbles are dragged out, elongated, broken, pulled apart, and ground down to a mosaic of small grains.

In Western Cornwall the rocks are rarely calcareous and true limestones are absent, but many of the greywackes are very impure, and contain much chlorite and epidote, with iron oxides, pyrites and granular sphene or leucoxene after ilmenite. The argillaceous laminæ have usually given rise to films of muscovite. Plagioclase and orthoclase felspar are often present as pebbles and show the same stages of demolition as the quartz. Some of these sediments contain hornblende, and Mr. J. Arthur Phillips * directed attention to a peculiar group of hornblendic greenstones of very basic character and probably of sedimentary origin which he found near Newlyn. In the fine crushed matrix there is often a considerable amount of minutely granular untwinned felspar. Altogether these greywackes bear a striking resemblance to some of the green beds of the Southern Highlands of Scotland, as these have been described by Mr. Barrow, Mr. Cunningham Craig, Mr. Clough, and Dr. Teall, but they are never found in the same highly crystalline state. It may also be mentioned that Dr. Teall has ascertained the occurrence of authigenic albite in some of the green altered sediments of Devonshire.

The Greenstones.—The igneous rocks associated with the killas or greywacke series have long been known as "greenstones," and this term it is proposed to retain as a group designation, as it sufficiently expresses their general character, while being sufficiently vague to include a diversity of special types. That they are igneous, and that most of them are intrusive, is generally accepted. The alteration which they have induced in the sediments in contact with them is sufficient to establish their nature. Good examples of this are seen at Newlyn, and at St. Ives, where the killas for a short distance from the greenstone is hardened and weathers to a pale banded grey rock which apparently belongs to the adinoles, though the characteristic structures are often but poorly developed or partly effaced by decomposition and by the later action of the granite intrusions.

Most of these greenstones are much sheared, though none of them have been converted into typical hornblendic schists. Their pyroxene has practically always disappeared in those which belong to the West of Cornwall, though visible usually in those which occur near St. Austell. It is replaced by tufted aggregates of green amphibole, more rarely by compact masses, and as the fibres and needles are usually disposed along roughly parallel planes a diabase schist or greenstone schist is produced. Epidote, calcite, chlorite, leucoxene and pyrites are the commonest accessories, though it is hard to say in every case whether some of them are

* *Quart. Jour. Geol. Soc.* vol. xxxii, p. 165.

not really secondary and due to decomposition. The felspar has frequently recrystallised to some extent, as in the most sheared specimens it forms a fine mosaic of small clear grains, untwinned and filled with enclosures of all the other ingredients. Biotite is not common except where these rocks have been contact altered.

It is probably on the whole true that the massive sills of greenstone have been less sheared than the sediments around them, especially where these are argillaceous, but as in the grits, every stage of alteration can be found from rocks with well preserved original structures to those which have become entirely schistose. In the region west of Camborne it is occasionally possible to find small phacoids or lenticles in the greenstones which have resisted or have accidentally escaped shearing. Many of these show ophitic structure even in the hand specimen; under the microscope the original augite is seen to have been replaced by felted acicular amphibole, with or without chlorite. Large skeleton plates of ilmenite occur, altering to leucoxene. The structure is that of an ophitic diabase, though of the essential primary minerals only the felspar is left. It occurs in large, elongate, much-twinned crystals, such as are typical of the coarser diabases. There can be little doubt that such rocks were originally intrusive.

Another kind of igneous structure can also be detected frequently in the Cornish greenstones. Large idiomorphic felspars—often broken and dragged out—lie in a finer ground mass of plagioclase and secondary amphibole. Sometimes the remains of augite phenocrysts may be seen, converted into the usual fibrous hornblende. These rocks must have been andesitic basalts or augite porphyrites. There is no reason to doubt that many of them were intrusive, but in view of the abundance of chlorite and epidote in many of the grits it is open to suspicion that some of them may really represent interbedded lavas, and the grits may contain ashy materials. None of them, however, is vesicular, so far as is yet known, and the occurrence of porphyritic along with ophitic basic intrusions is too frequent to occasion surprise. In some of the greenstones near Penzance and St. Just there is a white spotting which at first glance resembles vesicular structure, but proves, on further investigation, to be really due to the combined operation of shearing and of contact action by the immediately adjacent granite.

At Newlyn and in several other places in that district there are varieties of greenstone which weather to a pale brown, and are obviously much more felspathic than the normal dark green rocks. These proved on analysis* to be of andesitic composition, and must have originated from andesitic basalts or augite porphyrites, of intermediate rather than of truly basic character. This supports the evidence obtained from microscopic examination. No acid rocks of any kind belong to the older igneous series, and till further

* Summary of Progress for 1901, p. 89.

analyses have been executed it remains doubtful whether picrites or peridotites occur, though their presence may be reasonably expected. As it seems certain that these rocks were affected by decomposition, both before they were sheared and after, it is necessary to exercise caution in drawing conclusions from the results of chemical investigation.

Garnet has been reported by more than one observer from the greenstones of Cornwall, though in comparison with the hornblende schists and epidiorites of Scotland, which are frequently garnetiferous, its scarcity is very striking. A fine example of a garnetiferous greenstone, however, has been mapped by Mr. J. B. Hill, and is well exposed in the railway cutting to the west of Camborne. The garnet is not uniformly disseminated through the rock; it forms irregular patches and streaks, a few inches in breadth, scattered here and there through the mass. This occurrence seemed so much of an anomaly when it was first reported that search was made in other parts of Cornwall for similar rocks, with the result that Mr. Clement Reid, Mr. J. B. Scrivenor and Mr. MacAlister have all succeeded in obtaining further specimens. In working through this material I have received much assistance from Mr. Scrivenor.

In no case is garnet the only exceptional mineral present. It is practically always accompanied by pale green pyroxene and by a variety of epidote so like this pyroxene in colour and optical properties as to be distinguished from it only with difficulty. Felspar (often untwinned), magnetite and pyrite, calcite, axinite, quartz, and tourmaline are also found in more or less abundance. Green hornblende, similar to that of the greenstones, is often absent, but sometimes present in considerable amount, and has, in some cases, resulted from uralitisation of the pyroxene above-mentioned. Those minerals may be divided into two groups. The epidote, calcite, garnet, felspar and pyroxene are very like in all their characters to the same minerals when produced from the contact alteration of impure limestones. It should be remarked, however, that idocrase and scapolite have not been found. The garnet is common garnet and dark brown as a rule, but is sometimes clear green and then may belong to spessartite. It is often irregular, but sometimes forms rhombic dodecahedra, the edges of which may be truncated by faces of the icositetrahedron. The other group of minerals has a close relationship to those which occur in the tin bearing veins, and the contact rocks around the granite. Axinite and tourmaline contain boron and are genetically connected with the fluoric and boric emanations from the granite during its consolidation. The mineral paragenesis is very similar to that reported by Professor Busz* in contact altered calcareous shales around the granite of Dartmoor; but datolite has not as yet been found in these rocks in Western Cornwall, and it is not likely that if it were present in the specimens examined it would have escaped detection.

* *Neues Jahrbuch für Mineralogie*, BB. xiii., 1901, p. 90.

It seems clear that we are here dealing with substances of a calcareous nature, which have been affected by the heat of the granite and to some extent modified in composition by the vapours it emitted. Now these garnetiferous streaks are most frequent in the greenstones in the immediate vicinity of the granites and are rarely found beyond their aureoles of thermal metamorphism. In one case, however, at Perran Sands, S. of Newquay, Mr. Scrivenor found garnet and pyroxene in nodules or veins in a greenstone, where the adjacent killas showed none of that spotting which is usually the first symptom of thermal alteration. This may be explained by supposing that they lie in a vein or fissure which served as a conduit for the heated vapours and liquids arising from the granite beneath, exactly in the same way as did the veins which contain tourmaline and tinstone; or alternatively it may be assumed that the original minerals of the garnetiferous rocks were more susceptible to thermal change than the argillaceous matters of the killas.

The distribution of the garnet-pyroxene streaks is also not without significance. They invariably form lenticles or gnarled and contorted patches which may be numerous or few and distant, and show no regularity either in their form or in their mode of occurrence. Quite the finest example of this which has come under my notice is seen on the sea cliffs and land exposures in the vicinity of Botallack Mine. There the margin of the granite is nearly parallel to the coast and only a short distance from it. The cliffs consist of greenstone and killas so sheared and brecciated that in a small hand specimen half-a-dozen patches of each kind of rock may be detected. The greenstone has, probably, to some extent originally taken the form of thin veins which ramified through the finely-bedded shales, and the whole mass has been kneaded together by earth movements till a complex breccia has been formed, an irregular crush conglomerate in which the fragments, though of all sizes, are still angular or subovoid. The greenstone, before it was sheared, was probably considerably decomposed, for it varies greatly in aspect, being sometimes pale grey, at other times dark green and occasionally brown. At a later period contact alteration by the granite has converted the mixed rock into a hard brittle splintery hornfels which, with its patches of brown, dark green, pale green, and grey, would be a fine ornamental stone, were it not so intractable and irregularly jointed. The killas has passed into a brown biotite hornfels, the greenstone into a dark green diabase hornfels; veins of acicular actinolite run through the matrix; the grey and pale green patches are mostly pyroxene, epidote and felspar. In these rocks garnet is frequent, sometimes forming large masses; axinite and tourmaline are rare. Decomposition followed by shearing have produced a breccia of rotten diabase with phacoids of less sheared rock embedded in secondary minerals, such as calcite and dolomite, chlorite, uralite, and various zeolites. From the latter the garnetiferous patches,

rich in pale pyroxene and epidote, have formed, and hence their similarity to the calc silicate hornfelses.

Contact Alteration in the Greenstones.—The thermal alteration of the West Cornish greenstones, alluded to above, is a subject of much interest and of considerable difficulty. The less advanced stages are those about which there is most uncertainty. When the finer greenstones have been converted into dark, lustrous, flinty hornfelses, such as are admirably exposed in the small mass which rests on the granite at Tater Du, a little south of Lamorna Cove, they bear a certain resemblance to the most intensely altered sediments, and all the more because they usually contain fine scales of dark brown biotite which lie in parallel bands. Along these the rock readily parts when struck with the hammer, and the broken surfaces have then a brown colour and a bronzy appearance. The microscope shows that these extreme phases of the hornfelsing of basic igneous rocks consist of hornblende, brown or greenish-brown in colour, and clear fresh re-crystallised felspar in small rounded or equi-dimensional grains which unite to produce a well-defined pavement structure. Often the hornblende and the felspar are each aggregated along parallel lines, so that the rock is banded, though this is not, as a rule, obvious in the hand specimen, and when biotite is present, as is usually the case, it forms films by which the banding is rendered more pronounced. Apatite, iron oxides, pyrites and sphene are the commonest accessories, but a pale green augite occurs sometimes, and, like the other minerals, is not an original ingredient, but has been developed during the re-crystallisation through which the rock has passed.

It is easy to find every stage from this completely reconstructed type to rocks in which the changes are of so indefinite a kind that it is difficult to say how far they may be the result of weathering and of shearing, and to what extent they are to be ascribed to thermal action. Green pyroxene is found only in the most highly altered hornfelses; brown biotite and brownish-green compact hornblende are commoner but indicate also that the alteration has been considerable. Many of the greenstones which, undoubtedly, show induration in the hand specimen, consist essentially of fibrous green hornblende scattered through a matrix of soda lime felspar and contain no minerals which are not also found in plenty in rocks which lie entirely beyond the aurioles of metamorphism. The structure is then either the sheared ophitic or the sheared porphyritic mentioned above, or occasionally the finely granulitic and mylonitic. It seems reasonable to believe that the complete uralitisation which the greenstones, as a whole, show, may have been accelerated by even comparatively slight rise of temperature, but it should not be forgotten that in West Cornwall the shearing movements appear to have been more intense than in the eastern part of the county, and the scarcity or complete absence of original pyroxene may be due to this cause alone. The re-crystallisation of

the greenstones, and especially of their original felspar, must have required a comparatively high temperature, for it is only in the inner contact zones that it is found complete. On the other hand, the production of a small amount of new, water-clear, interstitial felspar (approaching albite in composition) between the larger grains of original plagioclase is so widespread that it was probably one of the first changes to be produced.

The Granites.—The granite masses which are so conspicuous a feature of the geology of this district are remarkably uniform in character throughout. Occasionally their margins are fine-grained, at other times they have a distinct parallel structure. Finer-grained and coarser varieties occur, and in the Land's End area, the former seem to be intrusive in the latter. Some of the granites contain porphyritic felspars in great abundance and of large size (near Lamorna Cove they are occasionally six inches in diameter), others contain few. In a fine granite streaks or *schlieren* of coarsely porphyritic character may be found. Dark basic segregations, rich in biotite, plagioclase, apatite, and iron oxides occur commonly. Tourmaline is widespread but variable in its distribution, being sometimes scattered nearly uniformly through the whole rock mass, but often is much more abundant near the margin of the intrusion, or along certain veins which have served to give passage to ascending gases or vapours. In the peripheral parts of the granites true pegmatities are frequent; they consist of large crystals of orthoclase perthite, with quartz, muscovite, and less commonly topaz, gilbertite and fluorspar. Threads of fine tourmaline granite often penetrate the pegmatite veins, showing that these latter formed in fissures in the already consolidated but still hot edges of the mass, and that at a later period fresh molten material welled up from beneath and rapidly cooled down. Aplite dykes are rare, though sometimes found cutting the granite; they seem to have no intimate connection with the porphyritic elvans. Evidence of magmatic differentiation is practically absent, there are none of the marginal diorites, hyperites, hornblendites, pyroxenites and peridotites which in infinite diversity accompany the newer granites of Scotland. The first impression the Cornish granites produce is apt to be that of a general monotony, but they present so many problems of their own that this is only transient and soon gives place to absorbing interest in the study of their genesis and history.

There are three minerals of the Cornish granites which, being somewhat unusual, may receive special notice. They are topaz, andalusite and cordierite (pinite). Topaz appears to be more widespread than is generally believed. It occurs not only in the greisens and in the pegmatites, but is also common in the granites, especially the finer varieties, and in the schorl rock. It is never idiomorphic except when formed in cavities or pegmatite veins. Andalusite is not at all uncommon, in fact it has always been found where a series of half-a-dozen slides of Cornish granites have been examined. It is nearly always pleochroic with the beautiful rose-pink tint so

characteristic of this mineral, but perfectly colourless and non-pleochroic crystals are also seen. There is reason to believe that it is most abundant near the edges of the granite masses, though not by any means confined to them. Where enclosures of killas are numerous andalusite is especially common, a fact which would lead to the opinion that its presence arises from the absorption of the aluminous materials of the shales. Pinite in large six-sided crystals wth flat terminations is a well known Cornish mineral. Its external form is singularly constant; its optical properties vary greatly. There can hardly be any doubt that it is secondary after cordierite, but fresh cordierite has never been detected in the centres of the pinite pseudomorphs or in six-sided crystals in any Cornish granite rocks. Like the andalusite, it is of widespread occurrence, but it seems also to be most frequent where enclosures of killas have been undergoing resorption. I have not yet found tinstone as a primary original ingredient of any of the granites; where it occurs there are also traces of silicification and the rock tends to assume the aspect of a greisen.

The zone of schorl rock which intervenes between the normal granite and the metamorphic aureole has received the attention of many petrologists, including Dr. J. J. H. Teall*, Professor Bonney†, and Mr. John Scrivenor‡. Its main features are consequently sufficiently well known to require no detailed description. It is exceedingly well seen at Mouseholes and Cape Cornwall, where the schorl rock has evidently been produced from the granite at a time when the margin had already consolidated, but the deeper-seated parts of the mass were still in process of crystallisation. The change is really metasomatic and was induced by the fluoric and boric vapours liberated by the interior granite when it began to crystallise and could no longer retain them in solution. The original structures of the granite are still recognisable in the schorl rock. The best instance of this is the porphyritic variety—Trevalganite—which Mr. Reid has obtained near Carbis Bay, where pseudomorphs after large idiomorphic felspars lie in a matrix of quartz and tourmaline. The felspar has been changed into granular white quartz with scattered tourmaline needles. The matrix is much darker in colour and far richer in tourmaline, which seems to have derived its iron and magnesia mostly from the original biotite. The sediments and greenstones in contact with the granite are also filled with tourmaline and the killas becomes a dark, hard, banded tourmaline schist.

The Greisens.—The greisen veins have also attracted the notice of many geologists and have recently been specially investigated by Mr. Scrivenor at Cligga Head. As a rule the greisen is produced from the granite by a process of silicification and the replacement of the

* British Petrography, p. 315.
† *Min. Mag.*, vol. i., p. 219, 1877.
‡ *Quart. Jour. Geol. Soc.*, vol. lix., p. 142, 1903.

felspar and biotite by white mica and tourmaline. Exactly similar changes take place in some of the elvans. The phenocrysts of quartz remain, but all the felspar vanishes, being replaced by a mosaic of large, very irregular, interlocking quartz grains which are highly turbid from the immense number of small scales of mica which they enclose. Topaz is also present occasionally as in the greisens, and tourmaline is more or less local. In some cases the killas has been affected by the same agencies and is converted into a silvery schist consisting of large scales of white mica with small grains of quartz and fine needles of tourmaline.

The Stanniferous Veins.—These modifications of granite, elvan and killas are the usual accompaniments of the stanniferous veins, with which they have undoubtedly a close genetic connection. In the veinstones quartz, tourmaline, and a rather strongly polarising chlorite, are the commonest minerals. Pyrites, arsenopyrite, chalcopyrite, fluorspar and apatite are rarely absent. The rocks which are worked as tin ores vary greatly in character and in origin. Altered granites, killas and true vein deposits may all contain sufficient tinstone to enable them to be worked for the metal. The true quartz lodes with cassiterite are very interesting, as it is possible in some cases to show that they have a complex history, as was pointed out by Mr. Collins.* The successive stages of their formation can be made out with the help of the microscope and it can be shown that the fissures have been opened, filled with quartzose vein stuff which was then crushed up by movement of the walls, and that these processes have been repeated three or four times in some of the great lodes. Fragments of the first deposit lie scattered in a matrix of the second, which in turn may be broken and cemented together by a third infiltration.

The tin veins are undoubtedly later than the granites and the elvans, yet they show perfect cataclastic structures which are singularly rare in the igneous rocks. The later movements of adjustment seem to have taken advantage of the existence of the fissures, and instead of interstitial granulitisation taking place in the intrusive masses, these narrow veins of quartz, perhaps not entirely consolidated at the time, have yielded to the stresses, and in so doing have had their minerals shattered and ground down. This explains the occasional occurrence of gneissic or granulitic types of elvan and granite in Cornwall—a fact which has been brought to my notice by Mr. J. B. Hill. Where the main granites are entirely massive, some of the dykes or smaller sills are intensely sheared. Yet there is reason to believe that they are later than the granite itself in some cases. Similar facts are also known from the Scottish Highlands, where some of the pegmatites which have originated from the granite at a time when the main mass was nearly, if not quite, solid, are highly cataclastic while the granite itself rarely shows traces of the effects of mechanical deformation.

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* *Min. Mag.*, vol. iv., p. 1, 1880.

Contact Alteration in the Sediments.—The contact alteration produced on the greenstones by the granites has already been discussed. It remains only to consider briefly the chief effects on the killas and other sediments. The grits as usual prove very insusceptible; the changes in the shales are more marked. The breadth of the contact aureole varies up to perhaps one mile and its outer margin fades away by indefinite gradations into the unaltered country. The earliest stages are the development of a faint spotting with sometimes a more micaceous lustre on the cleavage planes, and is more obvious to naked eye observation in the field than in thin sections examined under the microscope. The spots have no sharp boundaries and are very often isotropic or have so weak a double refraction that it is almost invisible. Whether this is an original characteristic or not, is often not clear, as most of the specimens are undoubtedly much weathered. Perhaps the principal ingredient of the spots is really a chlorite which is of secondary origin. Nearer the granite the spots become more sharply distinguished from the mass of the rock, but their nature is still obscure and probably they are not all of the same composition. Many of them consist of small scales of a colourless micaceous mineral, not certainly primary. Others are rich in biotite, which has often weathered to chlorite. Often a uniform extinction can be seen over nearly the whole area of a spot, and then andalusite is being developed. From this point onward there is less difficulty. The crystals of andalusite become more and more individualised. Very soon the characteristic rosy pleochroism appears. At first their boundaries are irregular, but at a later period they frequently show traces of rectangular transverse sections. In the innermost contact zones andalusite abounds. It is strongly pleochroic and is often filled with dark enclosures. It is remarkable that these very rarely show any regularity in disposition. They may form a rude cross or a feathery pattern, but this is exceptional, and typical chiastolite has not been seen in any of the slides.

It is well known that many of the shales have been filled with tourmaline by the action of the granite, but in my experience this is less common than is generally believed, and is mostly confined to the immediate vicinity of the intrusive masses and to the tinstone veins and the altered country rock adjoining them. Brown biotite in small deeply pleochroic scales is much more frequently produced than tourmaline by contact alteration of the shales. There are many parts of the aureoles in which tourmaline is rare. In other places altered killas will be found at some distance from the granite containing many small schorl needles visible on the splitting surfaces and very conspicuous in the microscopic section. These, there is reason to suspect, have come from the neighbourhood of the metalliferous lodes, as when fragments of the country rock are found in the brecciated quartz veins they are very often converted into an aggregate of brown and blue tourmaline and granular quartz,

sometimes with a little muscovite, but often entirely without biotite. The same changes are exhibited by the killas which forms the walls of the vein. As has been pointed out by Mr. Scrivenor the brown tourmaline appears to have formed after biotite (or in place of biotite in the hornfelses) while blue tourmaline is more frequent in the vein quartz deposited from aqueous solutions.

In the innermost zones of the aureoles of metamorphism, where the edge of the granite has been modified to form schorl rock, the altered sediments are usually also impregnated with schorl, but, on the whole, this kind of change is commoner in the igneous rock than in the sediments, and the breadth of the area over which it extends is never very considerable. It must be remembered also that part of the tourmaline may really be a primary ingredient of the phyllites, as in these rocks this mineral is rarely absent, but can usually be found as small indigo-blue well formed prisms scattered through the micaceous matrix.

Biotite hornfelses and andalusite biotite hornfelses are certainly the prevalent type of extreme thermal alteration products of the killas. Minerals of the calc silicate group are practically never seen, and this finds a simple explanation in the small percentage of original lime shown by analysis of the shales. Probably for the same reason garnet is very rare, only one case in which garnet is a component of the biotite hornfelses has come under my notice. At Porthmeor there is a thin band of intensely altered killas a few yards from the granite margin, which contains small, pale claret-coloured garnets, which are perfectly idiomorphic and are scattered freely through the rock.

Within the last few months it has been found that cordierite occurs in a certain number of the Cornish hornfelses, and is probably more common than had been suspected. Specimens collected at Tater Du, from the killas at its junction with the granite proved to contain a good deal of fresh cordierite, with the well known pleochroic halos around small enclosed zircons very clearly shown. The rocks in this quarter are remarkably fresh, and it is to this that the presence of the cordierite must be ascribed, for many of the specimens which do not show it contain rounded aggregates of small scales of a greenish micaceous mineral which is almost certainly pinite after cordierite. Especially in inland exposures in Cornwall it is very difficult to obtain fresh rock material for slicing, and on revising the collection of biotite hornfelses many were found in which the structure was that usually seen in cordierite biotite hornfels, and though no fresh cordierite was observed there was little room for doubt that it had been replaced by pinite. This mineral decomposes much more readily than andalusite and it will always be scarce in Cornwall where active glaciation has not removed the decomposed surface rocks.

In the Land's End granite there are many black rounded spots, as may be well seen in the polished slabs of this rock which are so extensively used as ornamental stones. Most of them are small,

but occasionally they are more than a foot in diameter. They are typically rounded or ovoid, though they may sometimes be sub-angular. Many of them are fragments of included killas, and their shape indicates that they have suffered considerable resorption. Others appear to be early basic segregations. In a well known paper, J. Arthur Phillips has given a most valuable description of the results of his investigation of these dark patches. The rounded killas fragments are nearly black in colour, but in good light have often a dark blue tint. Scattered through them are many flakes of brown biotite. They are usually so fine grained that their component minerals can only be determined with the help of the microscope. Slices were prepared from a number of dark enclosures in the granite at Lamorna, a little south of Newlyn. They proved to consist of quartz, biotite, muscovite, and felspar, with a considerable amount of andalusite, cordierite and sillimanite. The andalusite was of both the pleochroic and non-pleochroic varieties; the cordierite ideally fresh with strongly pleochroic halos; sillimanite was scarce, but was represented by small jointed colourless needles which had the typical cross section of this mineral.

Small grains of a green spinel were present also, as usually happens in such rocks. Mr. J. Arthur Phillips * has reported garnet in these enclosures, but as yet I have not come across it. Corundum has, however, been identified by Dr. Pollard and myself in the residue of the rock after treatment with acids and heavy solutions. These hornfelsed fragments represent the extreme phases of contact metamorphism on the argillaceous sediments of West Cornwall, and probably because they were obtained from the deeper parts of the principal granite quarries, where the rock is worked largely on account of its freshness, they show all the original minerals in an unusually good state of preservation.

The adjacent granite contains andalusite and pinite. There can be little doubt that these are due to saturation of the magma with absorbed sedimentary material, but their general occurrence, throughout the granite masses, would show that solution and resorption took place during the earlier stages of intrusion, and the dissolved material was pretty uniformly diffused at the time that crystallisation set in. There is, as already mentioned, a sharp distinction between the idiomorphic cordierite, which crystallised directly from the magma, and the irregular grains which occur in the cordierite biotite hornfelses.

Lamprophyres, &c.—The other rocks of Cornwall which especially interest the petrologist are the phonolite of the Wolf Rock, and the mica trap dykes. The former is so well known, and has been so often described and figured, that it needs no special comment. The mica traps are

* *Quart. Journ. Geol. Soc.* vol. xxxvi., p. 6., 1880.

absent from the Land's End area, but Mr. Clement Reid has collected specimens of a very well preserved minette from near Newquay. It is coarse-grained at the centre, finer at the edges, and contains, in addition to large plates of dark brown biotite, crystals of a pale green pyroxene and of dark brown idiomorphic hornblende. These lie in a matrix of panidiomorphic felspar with a little interstitial quartz. For the most part the dykes of this group are so much decomposed at their outcrop that they readily fall into a sandy brown earth, and it is difficult to prepare microscope sections of them.

III. The Coal Measures of the Valley of the Gwendraeth-fawr in South Wales.

BY T. C. CANTRILL, B.SC., AND E. E. L. DIXON, B.SC., F.G.S.

Mr. Cantrill. The list of principal veins given in the *Summary of Progress* for 1902 (p. 186) as occurring in the neighbourhood of Gors-gôch holds good, with certain modifications, as the veins are traced westwards down the Valley of the Gwendraeth-fawr. The following list has been drawn up from information obtained between Tumble and Pont Henry.

Viens of the neighbourhood of Pont Henry, in descending order.

Carway-fawr.	Ddugaled.	Gwendraeth.
Carway-fâch.	Hwch.	Triquart.
Upper Felen.	Stanllyd.	Pumpquart.
Lower Felen.	Gras-uchaf.	Little.
Big.	Gras-isaf.	Rhâs-fâch.
Green.	Brasslyd.	

Some of these veins are being worked at the Great Mountain Colliery, at Clos-yr-yn, at New Cwm Mawr, at Rhyd-y-cerig (New Dynant), at Pontyberem, at Pentremawr, and at Pont Henry. All the coals are anthracitic.

The principal modifications to be noted are: the disappearance westwards of the Charcoal Vein, the coming-in of the Hwch and Ddugaled Veins between the Stanllyd and the Green Veins, and the appearance of two veins known as the Felen or Yellow Veins, not far above the Big Vein. Finally, two veins known as the Carway Veins come in near Pontyberem and occupy a position relatively to the lower veins and to the Pennant which roughly corresponds with that held by the Red Vein east of Ammanford.

The Rhâs-fâch Vein, the lowest workable coal of the district, makes its appearance between Pontyberem and Pont Henry. The ironstone above the coal was once extensively dug and smelted at local furnaces; the coal was not of such importance as the ironstone, and is no longer worked.

The Pumpquart Vein, which is doubtless the Lower Pumpquart of the Cross Hands district, is the lowest vein now worked; it has an average thickness of 3 feet 9 inches. It has been worked near Foel Gastell, north-west of Cross Hands, and is then thrown south again by the Tumble Fault, a westerly upthrow which cuts the Limestone and Millstone Grit at Foel Gastell and has been touched in the workings at Parc-Dai and at the Great Mountain Colliery at Tumble. West of this fault the vein was worked at Parc-Dai Colliery and has lately been re-opened at Clos-yr-yn, where the outcrop describes a broad sigmoidal curve owing to a strongly marked anticline and syncline having a north-east and south-west direction. It then runs along the north side of the Gwendraeth-fawr Valley and is now being worked at New Cwm Mawr Colliery. At Clos-isaf it is thrown a short distance to the north again by the Dynant Fault, a westerly downthrow met with at the old Dynant workings. Beyond the fault it continues along the north side of the valley past Clyn Hebog, where it is being worked by the Pontyberem Colliery Company, to Pontyberem. There it crops under the alluvium, and was formerly worked by a shaft by the old Pontyberem Colliery Company.

It is next believed to crop under the screens of the present Pentremawr Colliery, and was worked by the old Capel Ifan Colliery, but soon crosses to the north side of the River Gwendraeth again, and is said to have been proved near Clyn-hîr, north of Pont Henry. From the tips of several old pits here a number of specimens of *Carbonicola* were obtained; these lamellibranchs have been observed in the shales above the Lower Pumpquart at several localities farther east, as noted in the *Summary of Progress* for 1902, p. 187.

At Pont Henry the vein is thrown southward by the Pont Henry Fault, an easterly downthrow hereabouts of some 60 yards.

The Triquart Vein averages about 2 feet 3 inches in thickness; it was worked at Parc-Dai, and near Cwm Mawr (Tre-fâch), but little is known of it at Pontyberem; it was, however, worked a little at the old Capel Ifan Colliery, and is said to crop under gravel near Pont Henry Bridge.

Of the Gwendraeth and the Brasslyd Veins between Cross Hands and Tre-fâch there is little information; the Gwendraeth, 2 feet 10 inches, has lately been re-opened at the New Dynant Colliery at Tre-fâch; south-west of Pontyberem it has been worked along the crop along the south side of the Gwendraeth Valley towards Pont Henry; it is being worked at Pentremawr Colliery, where it is 2 feet 9 inches thick, and at Pont Henry Colliery; and is supposed to crop under gravel a few yards south of Port Henry Bridge. The Brasslyd Vein, west of Pontyberem, was worked at the old Pentremawr Colliery and thence westwards; it is being worked at the present Pentremawr Colliery where it is 2 feet 8 inches thick, and at Pont Henry Colliery.

The remaining veins up to and including the Ddugaled presumably crop out along the south side of the Gwendraeth-fawr

Valley between Cross Hands and Tumble, but in this region little is known about them. West of the latter place they are better known; some of them were worked in the neighbourhood of Dynant, where the Hwch and Ddugaled Veins appear for the first time, and at Pontyberem and thence towards Pont Henry.

The Green and the Big Veins have been worked almost continuously from Tumble westwards. They are being worked at Great Mountain Colliery, and their crops can be traced thence past Dynant (where they are cut by a westerly downthrow) and Pontyberem, as far as Capel Ifan Farm. Here the crops are thrown southwards by an obscure fault which appears to pass a little south of the farm in a nearly east and west direction with downthrow north. A disturbance, visible in the old quarries in the Stanllyd Rock, west of the farm, may be due to the fault. West of this disturbance the crops of the Green and the Big Veins may be traced by old workings south of Carnwallon towards Ynys Hafren near Pont Henry.

The Felen Veins come in between Pontyberem and Pont Henry; each vein overlies a bed of fireclay which was formerly worked at Ynys Hafren.

A thickness of some 500 or 600 feet of barren measures separates the veins last mentioned from the two Carway Veins on which there are old workings at Ty'n-y-cwm and Ty'n-y-wern, south of Pontyberem.

The Cockshot Rock which forms such a conspicuous feature at the base of the sandstone ground at Tumble becomes indefinite and impersistent at Pen-llwyn-gwyddau, south of Dynant, where it is cut by the Dynant or Morlais Valley Fault. West of the fault it is no longer traceable as a continuous bed, but appears to be represented by several distinct bands, none of which is persistent.

Above this horizon follows a mass of shales with some fine-grained sandstone and one or two thin coals, succeeded by a well-marked bed of sandstone, indistinguishable from pennant, which makes a bold feature at Bryn-banal and south of Maen-gwyn. Next follows a thick bed of shale with some sandstone, which brings us up to the coal which was formerly worked north of Pen-llwyn-uchaf (*Summary of Progress* for 1902, p. 189) and supposed to be the representative of the Ynysarwed or Rhondda No. 2 Vein of the regions to the east.

Mr. Dixon. Lower down in the Gwendraeth Valley the general sequence between the supposed representative of Rhondda No. 2 and the Farewell Rock may be estimated as follows:—

Descending section of the Lower Coal Series at Pont Yates.

	Thickness. Yds.	Ft.	In.
Brondini Vein (supposed Rhondda No. 2)	1	0	0
Shale	50	0	0
Pennant-like sandstone, with little shale	85	0	0
Sandy shale, etc.	120	0	0
Cockshot rock	7	0	0
Measures	60	0	0

	Thickness. Mr. Dixon. Yds.	Ft.	In.
William Edmond's Little Vein		1	6
Measures	150	0	0
Carway Fawr Vein	1	0	9
Measures	10	0	0
Carway Fâch Vein		1	6
Measures	155	0	0
Upper Felen Vein		1	8
Measures	45	0	0
Big Vein	absent ? to	1	8
Measures	14	0	0
Green Vein		2	8
Measures	18	0	0
Ddugaled Vein	unknown		
Measures	25	0	0
Stanllyd Vein (commonly believed to include the Hwch Vein)	3	0	0
Measures	20	0	0
Upper Gras Vein	1	0	0
Measures	9	0	0
Lower Gras Vein	1	1	0?
Measures	45	0	0
Brasslyd Vein	1	0	0
Measures	29	0	0
Gwendraeth Vein	1	0	0
Measures, believed to contain the Triquart Vein	77	0	0
Pumpquart Vein	1	0	9
Measures	20	0	0
Little Vein		1	6
Measures	46	0	0
Rhas-fâch Vein		1	8
Measures	10	0	0
Farewell Rock			
Total	1009	2	8

The Rhas-fâch Vein is about 20 inches thick, but was less in requisition than some thick pins of ironstone in the shales immediately above. These were once worked in many places on the north side of the Gwendraeth-fawr Valley, the westernmost of which was at Pont Newydd where the crop reaches the river. On the south side the vein, again with ironstone above and fireclay below, is said with some probability to have been proved beneath drift at Glassberry, but it is not known with certainty further to the south-west, though a thin vein which may represent it has been proved at Moat not far above the supposed Farewell Rock of that neighbourhood. The probable occurrence of the vein at Glassberry points to a strike-fault with downthrow to the north between that place and Pont Newydd.

The Pumpquart Vein varies but little from a thickness of 3 feet 9 inches to 4 feet. It underlies the northern slopes of the valley as far west as Tanherdy, where it is probably thrown up to the west by a north-north-west fault. The crop appears to have been found on the south side of the river near Bryn-y-fforest, and to run thence to Pwll-y-llygod. But within a distance of half a mile it crops again and apparently even a third time, in every case with a dip to

Mr. Dixon. the south-east, a state of affairs which can only be explained by strike-faults with a downthrow north. In an adit one of the faults can be seen to be an overthrust; the other is probably an overthrust also. A vein 20 yards below and overlain by a considerable thickness of sandstone must be the Little Vein if the Pumpquart hereabouts be correctly identified. For much of this information our thanks are due to Mr. Hansard, of Llanelly.

South of the Morlais, veins corresponding in position to the Pumpquart and Little have been proved, the latter in a line of old slants south of the Colliers' Arms, which expose sandstone above the coal, whilst the Pumpquart is possibly represented by a vein 4 feet thick proved in a recent trial slope at Cil-rhedyn.

The Gwendraeth and Brasslyd Veins are hidden by alluvium at Pont Yates, but they are thought to be represented by two veins which emerge at a point north-west of Fforest, between which and Fforest-fach they have been worked from the crop. To the south-west they are not known with certainty, but a vein which has been proved at Tre-goch may be the Gwendraeth.

The Gras Veins crop on the south side of the Gwendraeth river near Pont Yates, and are traceable at intervals as far as Plas-bach. South-west of this they have not been recognised with certainty, but the following tentative suggestions as to their identity are made on the strength of evidence partly supplied by Mr. Jacob, of New Carway Colliery, to whom our thanks are due for much assistance in the task of determining the structure of the ground between Fforest and Fforest-fach. Near the New Carway Colliery the position of the Gwendraeth and Brasslyd Veins is known with some probability. Above the Brasslyd, in a position which would correspond to one of the Gras Veins, a third coal has been found. This was opened in a slant and proved to end below in an overthrust with a downthrow north. Above this again, what is popularly supposed to be the Big Vein crops out at the Carway Old Colliery, where also another vein was proved to lie 38 yards below it. If the "Big" Vein is correctly identified, the vein below it would probably be the Green. But it is considered by Mr. Jacob that this so-called Green Vein is identical in character with the vein lost in the slant previously mentioned. It seems, therefore, that these two are one and the same vein, displaced by the overthrust, and that this vein represents one of the Gras Veins. The downthrow of the overthrust on this theory would amount to 40 yards. The seam north of the overthrust has not been traced to the south-west, but what we believe to be the same seam south of the overthrust has been worked as far as Nant-y-gro.

Turning now to the Stanllyd Vein we get further light on the correlation of the veins of the Pont Yates and Carway districts. The Stanllyd Vein rises from beneath the Gwendraeth alluvium, near Ynys-Hafren, and has been worked at the crop between Pont Yates and Plas-bach, where its thickness was 9 feet. In

places it reached a thickness of 15 feet, but yielded a high per- Mr. Dixon.
centage of small coal. To the south-west it has not hitherto been recognised, but if the "Green" Vein of Carway be really one of the Gras Veins, as appears probable from the above considerations, the "Big" Vein of that district must be the Stanllyd. Confirmatory evidence of the relations of these veins has been obtained at the surface. The true "Big" Vein has been worked as far south as Pont Yates, where it is said to have dwindled to a thickness of 20 inches. Upon it lies a sandstone which appears to be traceable, after the disappearance of the coal, as far as Fforest. There the "Big" Vein of Carway comes in, but at some distance below the sandstone. It would seem, therefore, that the true Big Vein dies away near Pont Yates, and that the "Big" Vein of Carway corresponds better with the Stanllyd, both in thickness and position. It was extensively worked at one time, and its crop has been proved as far as Nant-y-gro.

The Ddugaled Vein has probably been wrought about Pont Yates from some of the numerous pits between the Stanllyd and Green Veins, but nothing is known of it with certainty.

The Green Vein has certainly been wrought as far as Pont Yates, and apparently as far as, but not beyond, the dingle above the old Plas-bach Colliery. There is no evidence for the general belief that it is the "Green" Vein of Carway.

There are several Felen Veins above the Big Vein. One, about 45 yards above it, rests on 2 feet of good fireclay.

As is seen from the section given on p. 164, there is a considerable thickness of practically barren measures between the Big and Carway Veins. The latter, one or both, are traceable almost continuously as far as the neighbourhood of Allt-y-sgrach, north of Trim-saran, where they disappear beneath drift. Above the Carway-fawr, but at a variable distance, is a bed of sandstone, which at Dan-y-banc is 24 feet thick, and closely resembles Pennant.

William Edmond's Little Vein, 15 to 20 inches thick, was worked between Cwm-gelwr and Herber-deg, and is not known elsewhere.

The Cockshot Rock, as already mentioned (p. 164), appears to occur intermittently, but approximately on one horizon. It is exposed at Tir-christopher, in the Ffou dingle north-east of Ty-gwyn, and near Herber-deg, but is possibly absent between these places. It has not been recognised south of Herber-deg. Above it coals are few and thin, and the shales estimated as 120 yards thick in the section are sandy and interbedded with fine sandstones. They are followed by a mass of sandstone indistinguishable from Pennant, and about 85 yards thick. Upon this rest about 50 yards of shale succeeded by the Brondini Vein, the supposed representative of Rhondda No. 2. On this supposition the sandstones referred to would correspond to the Llynfi Rock, which lies below the representative of Rhondda No. 2, near Maesteg and elsewhere.

In the Trim-saran district, south of the Morlais, the sequence differs from that in the Pont Yates district described above. The possible

Mr. Dixon

representatives of the Farewell Rock, and of the Rhas-fâch, Little, and Pumpquart Veins, have already been mentioned (p. 166), and we may next endeavour to recognise the base of the massive sandstones which we take to represent the Llynfi Rock. There can be little doubt that that base either runs somewhere along the upper part of the conspicuous northern scarp of Mynydd Pen-bre or corresponds to the Cenrhos Vein which lies at the foot of a thick sandstone. Lower down in the scarp there crops out a considerable thickness of shales with several coals, which, however, are being little worked at present. Below these again a series of important coals which are being worked at Trim-saran Colliery, is traceable by old workings westwards to beyond Syddyn, and then disappears beneath drift. Between this place and Cil-rhedyn, where the Pumpquart Vein appears to crop, some old pits indicate the presence of several veins between Llandyry and Glan-morlais. Unless there is faulting and folding on a large scale the Trim-saran series must be considerably above these Llandyry coals. We have evidence, therefore, of two series of veins, which may represent the Carway group and the Gwendraeth group of Pont Yates respectively. But as the examination of the district is not yet complete, and as it is impossible to state that there is not folding and faulting, the correlation of the Trim-saran series with the Carway seams is reserved for the present.

FAULTS AND DISTURBANCES.

Mr. Cantrill.

The chief faults having a north-north-west direction have been alluded to already. Besides these there are several having a west-south-west and east-north-east direction; one of these consists of a sharp anticline which traverses the Lower Pumpquart Vein at Clyn Hebog Colliery, Pontyberem. A more obscure disturbance is to be seen at Capel Ifan Farm, between Pontyberem and Pont Henry; it runs east and west, and appears to have the effect of a downthrow north, bringing the Ddugaled Vein on the north against the Stanllyd on the south; but in the underground workings of the Pentremawr Colliery it has not yet been identified.

North-north-westerly Faults.

Mr. Dixon.

The Pont Henry fault was proved at Ynys-Hafren in working the Green Vein. The easterly downthrow of the actual dislocation there is small, but the displacement of the crop is considerably increased by the steep easterly dip accompanying the fault. It has not been proved to the south, but it probably passes up the lower part of the dingle below Ffou, where there is a persistent easterly dip. The workings in the Carway-fawr Vein proved that it does not extend so far south as Ffou.

A similar fault appears to cross the Gwendraeth, about a mile to the west. South of the river the workings of the veins, with the exception of those on the Carway-fawr from the Gwendraeth

slope, both at the surface and in the deep cease on either side of the dingle below Dan-y-quarry. The coals as at present identified are not in line on opposite sides of the dingle, and indicate a considerable easterly downthrow, which, however, dies away to the south as it only slightly displaces the base of the sandstone at Dan-y-quarry. Mr. Dixon.

Another easterly downthrow has been proved at Cwm-bach in working the Rhas-fach ironstones. It is small, but appears to be the continuation of a larger fault proved to the north. It has not been traced south of the Gwendraeth.

Again a fault with downthrow to the east crosses the Millstone Grit of Mynydd-y-gareg, north-west of Goetre, and appears to pass down the dingle above Morfa-bach, but cannot be found south of the Gwendraeth.

North and west of Kidwelly a series of small breaks fringes the north side of the Kidwelly disturbance presently to be described. They trend generally northwards with a westerly downthrow.

Disturbances ranging in direction from east and west to north-east and south-west.

West of Gelli-hir where the westward continuation of the Llannon disturbance* is obscured by drift we fail to find evidence of similar movements for a distance of two miles, until, west of Ty-canol, a sharp fold crosses the Carway-fawr Vein, running east-north-east and characterised by a steep dip along its northern limb. It rapidly dies out to the north-east and disappears beneath drift to the south-west. Between this and the Gwendraeth-fawr evidence has been obtained of a series of strike-faults, which in some cases, as previously mentioned (p. 166), have been proved to be over-thrusts with downthrows to the north. These also die out to the north-east, and to the south-west disappear in a disturbance now to be described.

A belt of drift-covered ground in which rock is rarely seen, but when visible is disturbed, extends westwards through a break in the hills west of Five Roads. It follows what appears to be a line of disturbance running a little north of west and throwing the strata down to the north. There are several circumstances in support of this view. In the first place, the supposed disturbance lies nearly in line with the disturbed belt to the east which crosses the Mynydd Mawr Railway between Horeb and Trefanau.† In the second place the beds on the north and south dip away from one another not only near Horeb but again at Cil-feri-isaf and Trim-saran to the west. Lastly, where the Morlais has laid bare a strip of rock in place along the same line the measures are contorted and traversed by innumerable east and west overthrusts. The disturbance, therefore, appears

* *Summary of Progress* for 1902, p. 184.
† Op. cit. pp. 179, 180.

Mr. Dixon. to keep a fairly straight course, on the whole a little north of west. This direction would carry it about half a mile south of Kidwelly.

At Horeb there is nothing to show what is the effect of the disturbance further than that it is a broken anticline parallel to the remarkable little overthrust already described.* Near Trimsaran we have some evidence that there may be a considerable downthrow to the north. The Brondini Vein as already stated we believe to be Rhondda No. 2, and the sandstone below it for a distance of 135 yards to represent the Llynfi Rock. The base of this rock at Dan-y-quarry on the north side ranges for the outcrop of the Drap Vein on the south side, which, according to Logan, lies much lower down in the series,† the sandstone-base being situated at least half a mile further south. Again the crop of the Pumpquart Vein on the north side ranges for the exposure of Farewell Rock near Moat on the south side, which also points to a downthrow north.

It may be noticed that the Llannon disturbance and the overthrusts west of Carway run into the belt of disturbed ground at an oblique angle and are not known to reappear to the south of it.

Between Pont Spudder and Kidwelly the ground is obscured by drift, but at the latter place a belt of fractures runs in a north-easterly direction up the valley of the Gwendraeth-fach with a downthrow south which steadily diminishes eastwards. One fault has been traced to its termination, but the others continue as far as the ground has been examined.

The fault previously mentioned (p. 169) as crossing the Millstone Grit north-west of Goetre can be followed in a meandering northerly course across the quartzites of Mynydd-y-gareg, which it throws down to the east. Just past the crest of the ridge the fault comes to an end, but 80 yards further to the east a similar easterly downthrow commences, the appearances strongly suggesting that the fault has been broken through by another and shifted. On further search it was found that there is evidence of such a cross-fault occupying a pronounced hollow which crosses the ridge in a north-west direction. This north-west fault would thus appear to be later than the northerly fault, but on the other hand, though not agreeing with the north-east faults in direction, it may belong to that system of disturbances. It differs from the north-north-west system in the fact that its course across the scarp is marked by a conspicuous hollow. A clue to the nature of the movement is furnished by the slickensiding accompanying it, which slants down south-east at nearly the same angle as the general dip of the beds. Though, therefore, its displacement of the outcrops is small its large shift of the northerly fault is intelligible. Again, in its neighbourhood the sandstones with an interbedded shale show a form of dislocation which suggests compression and overthrusting rather than normal faulting.

* *Summary of Progress* for 1902, p. 180.

† Geological Survey Vertical Sections, Sheet 1.

Some of the veins in the Carboniferous Limestone and to a less extent those in the Old Red Sandstone contain small quantities of copper pyrites, galena and chalybite, associated with quartz. These lodes occur in vertical fissures having a north-west or north-north-west direction, or in slickensided bedding-planes. Though they show no definite connection with the north-east system of disturbances they are confined to the area affected by it. Mr. Dixon.

West of the town the Kidwelly disturbance appears to curve into a more east-and-west direction, and at the same time the strike of the Old Red Sandstone bends sharply in the same direction. This suggests that the Trim-saran disturbance, which as we have seen (p. 170) would lie about half a mile south of Kidwelly, continues west of Pont Spudder at least as far as the mouth of the Gwendraeth-fach. Near here it would presumably be joined by the Kidwelly disturbance, which would run into it at about the same angle as the small overthrusts east of the Gwendraeth-fawr, mentioned on p. 166. The south-westerly dip of the shales at Kidwelly suggests the existence of Coal Measures under the sea to the south, but in this connection the possible presence there of the Trim-saran disturbance must be taken into account.

IV. Further Notes on the Chipping Sodbury Cutting on the South Wales Direct Railway.

BY A. STRAHAN, M.A., F.R.S.

This cutting, which was described in the *Summary of Progress* for 1902, p. 192, was completed in 1903 and revisited in October of that year, when the following additional notes were made on the Palæozoic Rocks.*

The uppermost beds of the Carboniferous Limestone crop out west of Lilliput Bridge and are exposed to a thickness of 400 feet. Their top is concealed by Keuper Marls and dolomites, which rest in hollows, and even under ledges, carved out of an oolitic Carboniferous Limestone. For the reasons stated (*op. cit.*, p. 194) this oolite must lie close to, if not actually at the top of, the Carboniferous Limestone. Next below it there occur fine grits and purplish shales followed by dark mottled limestones with black carbonaceous clays. The last-named closely resemble some strata occurring at the same horizon in Gower and which were described by Mr. Tiddeman under the name of Mumbles Head Beds in the *Summary of Progress* for 1901, p. 41. In Gower they contain a thin coal-smut, thought by Mr. Tiddeman to have been formed from sea-weeds, and yield a minute gasteropod.

From Lilliput Bridge eastwards for about 100 yards the cutting exhibits a further thickness of about 195 feet of limestone. Here

* See also paper by S. H. Reynolds and A. Vaughan, *Quart. Journ. Geol. Soc.*, Vol. lx., p. 195.

the grit which formed the crag in the Rhætic sea crops out (*op. cit.*, p. 193) and the following section commences :—

Descending Section from 100 *yards east of Lilliput Bridge to Kingrove Bridge.*

	Ft.
Thin bands of ripple-marked grit and shale, with ferruginous staining	2½
Massive grit, coarse-grained and with an occasional quartz-pebble up to an inch in length in the lower part	11½
Greenish shale and marl	1
Impure limestone	3
Blue clay with irregular bands of limestone	8
Limestone and shale in thin laminæ	2
Reddish marl and rock-marl with limestone, about	42
Black smooth-textured limestone, thinly bedded with shale-partings, about	165
Massive grey oolitic limestone, dolomitised in places at the top and passing down into dark bedded limestones below	300

Here the cutting is crossed by Kingrove Bridge, which occupies the site of the timber bridge referred to in the *Summary of Progress* for 1902 (Fig.*). Under the bridge the nearly level platform on which the Rhætic shales rest, drops down suddenly from about 12 feet to 4 feet above the rails, and 50 yards further east descends below the rails. In this distance of 50 yards the Carboniferous rock is thinly bedded, split up by shales, and may be more correctly described as calcareous grit than as limestone. For the next 61 yards the Rhætic base lies below the bottom of the cutting, but the older rock then re-emerges and for a distance of 38 yards shows the same character as before. To these calcareous grits and shales we may ascribe a thickness of 300 feet, including the strata which may be presumed to underlie the interval of 61 yards. At this point, 149 yards east of Kingrove Bridge, a pre-Triassic fault, which is best seen on the south side of the cutting, interrupts the sequence in the Carboniferous Rocks. The downthrow, judged by the hade, must be to the east, but is probably small. On its east side the fault introduces the following strata :—

Section commencing 149 *yards east of Kingrove Bridge.*

	Ft.
Red massive limestone, passing down	8
Red banded grit	6
Greenish mudstone	14
Calcareous platy beds	24
Pale-blue mudstones and thin calcareous grit	20
Grey micaceous grits, with red conglomeratic bands in the upper part ; irregularly bedded ; seen to	100

It appears from this section that no definite plane of demarcation exists between the Carboniferous Limestone and Old Red Sandstone. The Lower Limestone Shales may be considered to commence

* The length of cutting illustrated in this figure is about 1,100 yards. The vertical scale is exaggerated.

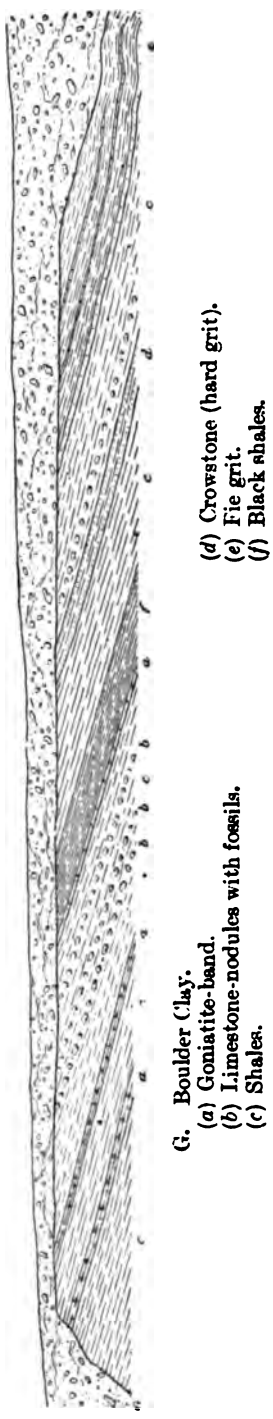

FIG. 10.—*Section along the Leek and Waterhouses Light Railway, Staffordshire.*

at the Kingrove Bridge, and it may be assumed that soft strata belonging to this group underlie the gap of 61 yards where the Rhætic base lies below the rails. In the same group also must be placed the calcareous grits of the next 38 yards, but then a change commences. A red tinge appears in some of the beds, in a manner which suggests a temporary recurrence of Old Red conditions, but it is not till we reach the grey grits with the red conglomeratic bands that we recognise Old Red Sandstone in its typical aspect. The details of the whole Carboniferous exposure of the cutting may be summarised as follows :—

	Ft.
Limestones, etc., west of Lilliput Bridge - -	400
Limestones to the grit 100 yards east of Lilliput Bridge - - -	195
Grits, limestones, etc., enumerated in section given above between Lilliput and Kingrove Bridges - - -	537
Lower Limestone Shales, from Kingrove Bridge to the fault - -	300
Passage-beds - - -	72
Old Red Sandstone, seen to	100

The total thickness of strata assignable to the Carboniferous Limestone Series therefore exceeds 1,500 feet.

V. NOTES ON THE LEEK AND WATERHOUSES LIGHT RAILWAY IN STAFFORDSHIRE.

BY W. GIBSON, B.SC., F.G.S.

This line leaves the Churnet Valley near Cheddleton Junction and continues in a general easterly direction to Waterhouses.

The line traverses the moorland formed of the shales the Pendleside Series and passes on to the Carboniferou near Waterhouses. The cuttings are not completed, information it is hoped will be obtained during the yea

The Pendleside Series is found to be thrown into sharp folds which become more pronounced and compl Carboniferous Limestone of the Weaver Hills is app layer of boulder clay, in places over 30 feet thick, cov the ground; but through this, as near the Manifold (larger prominences protrude. The blocks are exclusi origin, and it would appear that we are here dealing wi of the Pennine Glacier and not with that of the great Sheet.

The most interesting cutting is that near the Blacks two and a half miles from Leek, on the main road to The chief characteristic of the section is the number fossiliferous bands and nodules of dark earthy limes *Goniatites*. Their position in the Pendleside succession doubtful, but similar bands are commonest elsewhere lower portion of the sequence.

APPENDIX VI.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH GASTEROPODA and SCAPHOPODA from the LOWER, MIDDLE and UPPER OOLITES, preserved in the MUSEUM of PRACTICAL GEOLOGY, London.*

BY H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species or variety. The indentity of some few specimens is not quite certain: these are marked [**Doubtful**]. The figures in brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed:—

Ann. Mag. Nat. Hist.: Annals and Magazine of Natural History, London.

"Cotteswold Hills": "The Cotteswold Hills Hand-book," by J. Lycett, London.

Geol. Mag.: The Geological Magazine, London.

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London. "A Monograph of the Mollusca from the Great Oolite," by Prof. Morris and John Lycett, and Supplementary Monograph by John Lycett. (The dates quoted refer to year of *issue* only.)

Proc. Cotteswold Nat.: Proceedings of the Cotteswold Naturalists' Club, London.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

GREAT OOLITE.

Acteon bathonicum, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 16, p. 25.
Great Oolite. [9030] Bath.

Acteon phasianoides, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 28, p. 26.
Great Oolite. [9027] Minchinhampton.

Actæonina ? bulimoides, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 15, p. 104.
Great Oolite. [8151] Minchinhampton.

Actæonina olivæformis (Dunker).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 14, p. 103.
Great Oolite. [8152] Minchinhampton.

Acteonina scalaris, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc. Suppl., 1863, pl. xliv., f. 18, p. 28.
Great Oolite. [8153] Kirtlington, Oxfordshire.

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* A catalogue of the specimens from the Inferior Oolite was published in "The Summary of Progress" for 1902, pp. 222-228.

Alaria armata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 1, 1*a*, *c*, p. 16.
Great Oolite. [8259, 8260] Minchinhampton.

Alaria atractoides (F. A. E. Deslongchamps).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 7, 7*a*, p. 19.
Great Oolite. [8261] Minchinhampton.

Alaria ? cirrus (F. A. E. Deslongchamps).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 13, 13*a*, p. 22.
Great Oolite. [8262] Minchinhampton.

Alaria hamulus (F. A. E. Deslongchamps).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 4, 4*a*, *b*, p. 17.
Great Oolite. [8265] Minchinhampton.

Alaria hamus (F. A. E. Deslongchamps).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 2, 2*a*, *b*, p. 16.
Great Oolite. [8263, 8264] Minchinhampton.

Alaria hexagona, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii, f. 8, p. 19.
Great Oolite. [8267] Minchinhampton.

Alaria lævigata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 3, 3*a*, p. 17.
Great Oolite. [8268] Minchinhampton.

Alaria lævigata, Morris and Lycett.
J. Lycett, "Cotteswold Hills," 1857, pl. vii., f. 2, p. 149.
Great Oolite. [8291] Cotteswold Hills.

Alaria pagoda, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 6, p. 18.
Great Oolite. [8269] Minchinhampton.

Alaria paradoxa (F. A. E. Deslongchamps).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xiii., f. 3, p. 20.
Great Oolite. [8272, 8273] Minchinhampton.

Alaria paradoxa, var. **a**, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 9*a*, p. 20.
Great Oolite. [8271] Minchinhampton.

Alaria parvula, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 12*a*, *b*, p. 22.
Great Oolite. [8270] Minchinhampton.

Alaria trifida (Phillips).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 11, 11*a*, *c*, p. 21.
Great Oolite. [8274, 8275, 8276] Minchinhampton.

Amberleya (Pagodus) nodosa (Buckman).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 19, p. 55 ; Suppl., 1863, pl. xli., f. 3, p. 19.
Great Oolite. [8206] Minchinhampton.

Brachytrema buccinoidea, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 17, p. 5.
Great Oolite. [8414] Minchinhampton.

Brachytrema Buvignieri, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 7, p. 24.
Great Oolite. [8410] Minchinhampton.

Brachytrema pygmæum, *vide* **Turbo pygmæus.**

Brachytrema sub-nodulosum, *vide* **Fusus ? sub-nodulosus.**

Brachytrema turbiniformis, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 35, 35*a*, p. 25.
Great Oolite. [8411] Minchinhampton.

Brachytrema varicosa, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 27, p. 5.
Great Oolite. [8415] Minchinhampton.

Bulla undulata, Bean.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 8, 8*a*, p. 96.
Great Oolite. [8149] Minchinhampton.

Ceritella acuta, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 17, 17*a*, 18, 18*a*, p. 37.
Great Oolite. [8389, 9193] Minchinhampton.

Ceritella conica, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 10, 10*a*, p. 39.
Great Oolite. [8390] Minchinhampton.

Ceritella fusiformis, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlv., f. 4, p. 12.
Great Oolite. [8395] Minchinhampton.

Ceritella gibbosa, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 17, p. 39.
Great Oolite. [8394] Minchinhampton.

Ceritella longiscata (Buvignier).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 14, p. 40.
Great Oolite. [8388] Minchinhampton.

Ceritella Lycettea (Buvignier).
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 25, p. 12.
Great Oolite. [8397] Minchinhampton.

Ceritella minutissima, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlv., f. 5, p. 11.
Great Oolite. [8396] Minchinhampton.

Ceritella mitralis, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 15, p. 39.
Great Oolite. [8393] Minchinhampton.

Ceritella Morrisea (Buvignier).
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 22, p. 12.
Great Oolite. [8398] Minchinhampton.

Ceritella planata, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 14, 14*a*, p. 38.
Great Oolite. [8392] Minchinhampton

Ceritella rissoides, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 7, p. 40.
Great Oolite. [8387] Minchinhampton.

Ceritella Sowerbii, Morris and Lycett. T
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 16, p. 38.
Great Oolite. [8396] Minchinhampton

Ceritella unilineata (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 13, p. 38.
Great Oolite. [8391] Minchinhampton.

Cerithium bathonicum, Lycett. T
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 19, p. 6.
Great Oolite. [8292] Minchinhampton.

Cerithium bulimoides, F. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 3, p. 7.
Great Oolite. [9022] Minchinhampton.

Cerithium limæforme, F. A. Roemer.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 2, p. 30.
Great Oolite. [8283] Minchinhampton.

Cerithium multiforme, Piette.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 20, p. 7.
Great Oolite. [8279] Kirtlington, Oxfordshire.

Cerithium pentagonum, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 22, p. 30.
Great Oolite. [8280] Minchinhampton.

Cerithium quadricinctum, Goldfuss.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 8, p. 29.
Great Oolite. [8281] Minchinhampton.

Cerithium Roissii (d'Archiac).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 14, 14*a*, p. 32.
Great Oolite. [8213] Minchinhampton.

Cerithium sexcostatum, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 3, 3*a*, p. 30.
Great Oolite. [8282] Bussage.

Cerithium? spiculum, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 1, p. 9. **Kilvertia**, p. 94.
Great Oolite. [9023] Minchinhampton.

Cerithium? strangulatum, d'Archiac.
Morris & Lycett, Mon. Pal Soc., Suppl., 1863, pl. xliv., f. 2, p. 8. **Kilvertia**, p. 94.
Great Oolite. [8285] Minchinhampton.

Cerithium? Witchelli, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 7, p. 10.
Great Oolite. [8284] Minchinhampton.

Chemnitzia hamptonensis, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 1, 1*a*, p. 50.
Great Oolite. [8308] Minchinhampton.

Chemnitzia Leckenbyi, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 4, p. 50.
Great Oolite. [8310] Minchinhampton.

Chemnitzia Lonsdalei, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 13, 13*a*, p. 49.
Great Oolite. [8311, 8318] Minchinhampton.

Chemnitzia phasianoides, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 5, p. 51.
Great Oolite. [8312] Minchinhampton.

Chemnitzia simplex, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 15, p. 49.
Great Oolite. [9021] Bisley Common.

Chemnitzia variabilis, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 7, 7*a*, *b*, p. 51.
Great Oolite. [8317] Minchinhampton.

Chemnitzia Wetherellii, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 5, 5*a*, p. 50.
Great Oolite. [8309] Minchinhampton.

Crossostoma ? discoideum, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f 7, 7*a*, p. 73. **Monodonta**, J. Lycett, Suppl., 1863, p. 123.
Great Oolite. [8207] Minchinhampton.

Crossostoma ? heliciforme, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 8, p. 73. **Monodonta**, J. Lycett, Suppl., 1863, p. 123.
Great Oolite. [9014] Minchinhampton.

Cylindrites acutus (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 9, 9*a*, *b*, p. 98.
J. Lycett, "Cotteswold Hills," 1857, pl. vii., f. 7, p. 168.
Great Oolite. [8154] Minchinhampton.

Cylindrites altus, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 12, 12*a*, *b*, p. 99.
Great Oolite. [8155] Minchinhampton.

Cylindrites brevis, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 13, 13*a*, *b*, p. 101.
Great Oolite. [8150] Minchinhampton.

Cylindrites bullatus, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 18, 18*a*—*c*, p. 102.
Great Oolite. [8156] Minchinhampton.

Cylindrites cylindricus, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 19, 19*a*–*c*, p. 100.
Great Oolite. [8158] Minchinhampton.

Cylindrites cuspidatus (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 10, 10*a*, p. 98.
Great Oolite. [9015] Minchinhampton.

Cylindrites excavatus, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 17, 17*a*, *b*, p. 100.
Great Oolite. [8157] Minchinhampton.

Cylindrites exigua, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 14, p. 24.
Great Oolite. [9026] Minchinhampton.

Cylindrites pyriformis, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 20, 20*a*–*c*, p. 102.
Great Oolite. [8159] Minchinhampton.

Cylindrites Thorenti (Buvignier).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 22, 22*a*–*c*, p. 101.
Great Oolite. [8160] Minchinhampton.

Delphinula alta, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 31, p. 71.
Great Oolite. [8208] Minchinhampton.

Delphinula Buckmani, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 8, p. 71.
Great Oolite. [8209] Minchinhampton.

Delphinula coronata (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 26, p. 70.
Great Oolite. [8210] Minchinhampton.

Eulima communis, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 21, 21*a*, p. 48.
Great Oolite. [8313] Minchinhampton.

Eulima pygmæa, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 1, p. 48. **E. vagans** junior. *Ibid.* 1855, p. 148.
Great Oolite. [8314] Bussage.

Eulima subglobosa, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 6, p. 49.
Great Oolite. [8316] Minchinhampton.

Eulima vagans, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 4, p. 48.
Great Oolite. [8315] Minchinhampton.

Eulima vagans junior, *vide* **E. pygmæa.**

Euspira canaliculata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 23, 23*a*, p. 45.
Great Oolite. [8321] Minchinhampton.

Euspira coronata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 9, p. 46.
Great Oolite. [8322] Minchinhampton.

Euspira pyramidata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 8, 8*a*, p. 46.
Great Oolite. [8324] Minchinhampton.

Euspira Sharpei, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 22, p. 46.
Great Oolite. [8323] Minchinhampton.

Euspira subcanaliculata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 13, p. 47.
Great Oolite. [8325] Minchinhampton.

Fibula variata, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc. Suppl., 1863, pl. xxxi., f. 4, 4*a*, p 16.
Great Oolite. [8211, 8212] Minchinhampton and Kirtlington.

Fusus coronatus, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 5, p. 23.
Great Oolite. [8417] Minchinhampton

Fusus multicostatus, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 6, 6*a*, p. 23.
Great Oolite. [8416] Minchinhampton.

Fusus? sub-nodulosus (d'Orbigny).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 9, 9*a*, p. 23. **Brachytrema**, J. Lycett, Suppl. 1863, p. 122.
Great Oolite. [8412] Minchinhampton.

Hydrobia caledonica, Tate. T.
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 8*a*, *b*, p. 349.
Infra-Oxfordian Estuarine. [8600,8601] Loch Bay, Dunvegan.

Kilvertia formosa, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 5, p. 95.
Great Oolite. [8286] Bussage.

Kilvertia spicula and **K. strangulata**, *vide* **Cerithium ?**

Leptoxis trochiformis, Tate. T.
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 4, p. 349.
Infra-Oxfordian Estuarine. [8607] Loch Bay, Dunvegan.

Melania ? inermis, Tate. T.
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 5*a*, *b*, p. 348.
Infra-Oxfordian Estuarine. [8604] Tor-vaig, Portree.

Monodonta composita, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlv., f. 6, p. 23.
Great Oolite. [9025] Minchinhampton.

Monodonta discoidea, *vide* **Crossostoma ?**

Monodonta formosa, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 6, 6*a*, *b*, p. 68.
Great Oolite. [8214] Minchinhampton.

Monodonta heliciformis, *vide* **Crossostoma ?**

Monodonta imbricata, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 3, 3*a*, p. 67.
Great Oolite. [8215] Minchinhampton.

Monodonta Labadyei (d'Archiac).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 2, 2*a*, p. 68.
Great Oolite. [8217] Minchinhampton.

Monodonta Lyellii, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 4, 4*a*, *b*, p. 67.
Great Oolite. [8216] Minchinhampton.

Monodonta sparsistriata, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlv., f. 9, p. 22.
Great Oolite. [8218] Minchinhampton.

Natica ambigua, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 5, p. 44.
Great Oolite. [8327] Minchinhampton.

Natica formosa, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 10, p. 42.
Great Oolite. [8326] Minchinhampton.

Natica globosa, F. A. Roemer.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 14, p 43.
Great Oolite. [8328] Minchinhampton.

Natica grandis, Muenster.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 12, p. 41.
Great Oolite. [8329] Minchinhampton.

Natica intermedia, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 1, 1*a*, p. 41.
Great Oolite. [8330] Minchinhampton.

Natica Michelini, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 2, 2*a*, 3, 3*a*, p. 44.
Great Oolite. [8370, 8371] Minchinhampton.

Natica Stricklandi, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 24, 24*a*, p. 42.
Great Oolite. [8372] Minchinhampton.

Natica Tancredi, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 11, p. 42.
Great Oolite. [8373] Minchinhampton.

Natica Verneuili, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vi., f. 6, 6*a*, 7, 7*a*, p. 44.
Great Oolite. [8374, 8375] Minchinhampton.

Nerinæa Dufrenoyi (d'Archiac).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 8 *c*, *d*, p. 34.
Great Oolite. [8287] Minchinhampton.

Nerinæa (Trochalia) Eudesii, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 6, 6*a*, p. 33.
Great Oolite. [8288] Minchinhampton.

Nerinæa Voltzii, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. vii., f. 11, 11*a*, p. 32.
Great Oolite. [8289, 8290] Minchinhampton.

Nerinæa Voltzii, J. A. E. Deslongchamps.
J. Lycett, "Cotteswold Hills," 1857, pl. vii., f. 6*a*, *b*, p. 168.
Great Oolite. [8376] Minchinhampton

Nerita Buvignieri, *vide* **Stomatia ?** **T.**

Nerita cancellata, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 15, 15*a*, p. 56.
Great Oolite. [8162] Minchinhampton.

Nerita hemisphærica, F. A. Roemer.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., figs. 14, 14*a*, 16, 16a, p. 58.
Great Oolite. [8163, 8164] Minchinhampton.

Nerita rugosa, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 17, 17*a*, p. 56.
Great Oolite. [8165] Minchinhampton.

Neritina arata, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 7, p. 348.
Infra-Oxfordian Estuarine. [8599] Loch Bay, Dunvegan.

Neritina staffinensis, Forbes **[Doubtful.]**
E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 13, p. 110.
Estuary Shales. [8646] Loch Staffin, Skye.

Neritina staffinensis, Forbes.
R. Tate, Q. J .G. S., vol. xxix., 1873, pl. xii., f. 6, p. 348.
Infra-Oxfordian Estuarine. [8608] Staffin, Skye.

Neritopsis striata, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 13, 13*a*, p. 59.
Great Oolite. [8168] Minchinhampton.

Neritopsis sulcosa (d'Archiac).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 12, p. 59.
Great Oolite. [8166] Minchinhampton.

Neritopsis varicosa, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 20, 20*a*, p. 106.
Great Oolite. [8167.] Minchinhampton.

Paludina scotica, Tate. T.
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 3, p. 349.
Infra-Oxfordian Estuarine. [8605] Loch Bay, Dunvegan.

Patella arachnoidea, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 8, 8*a*, *b*, p. 92.
Great Oolite. [8190] Minchinhampton.

Patella aubentonensis, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 7, 7*a*–*d*, p. 91.
Great Oolite. [8188, 8189] Minchinhampton.

Patella cingulata, Muenster.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 4, 4*a*–*d*, p. 88.
Great Oolite. [8191, 8192] Minchinhampton.

Patella cingulata junior, *vide* **P. nana**. T.

Patella inornata, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 11, 11*a*, p. 93.
Great Oolite. [9019] Minchinhampton.

Patella nana, Morris & Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 10, 10*a*, p. 93, **P. cingulata** junior, *Ibid.* 1855, p. 148.
Great Oolite. [9020] Minchinhampton.

Patella paradoxa, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 2, 2*a*, *b*, p. 90.
Great Oolite. [8204] Minchinhampton.

Patella Roemeri, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 6, 6*a*, *b*, p. 91.
Great Oolite. [8195] Minchinhampton.

Patella rugosa, J. Sowerby.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 1, 1*a*–*e*, p. 89.
Great Oolite. [8198, 8199] Minchinhampton.

Patella striatula, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 5, 5*a*, *b*, p. 91.
Great Oolite. [8197] Minchinhampton.

Patella sulcata, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 3, 3*a*, *b*, p. 90.
Great Oolite. [8196] Minchinhampton.

Patella suprajurensis, Buvignier.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 9, 9*a*, p. 92.
Great Oolite. [8200] Minchinhampton.

Phasianella acutiuscula, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 28, 28*a*, p. 75 ; Suppl. 1863, p. 122.
Great Oolite. [8221] Minchinhampton.

Phasianella elegans, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 27, 27*a*, p. 74.
Great Oolite. [8223] Minchinhampton.

Phasianella Leymeriei, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 31, 31*a*, p. 74.
Great Oolite. [8225] Minchinhampton.

Phasianella nuciformis, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 26, p. 75.
Great Oolite. [8224] Minchinhampton.

Phasianella parvula, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 29, 29*a*, p. 75.
Great Oolite. [8220] Minchinhampton.

Phasianella tumidula, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., pl. xi., f. 25, 25*a*, p. 76.
Great Oolite. [8222] Minchinhampton.

Pileolus lævis, G. B. Sowerby.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 37, 37*a*, *b*, p. 60.
Great Oolite. [8169] Minchinhampton.

Pileolus plicatus, G. B. Sowerby.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 36, 36*a–c*, p. 60.
Great Oolite. [8172] Minchinhampton.

Pleurotomaria composita, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 13, 13*a*, p. 80.
Great Oolite. [8176] Minchinhampton.

Pleurotomaria discoidea, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 12, p. 78.
Great Oolite. [8177] Minchinhampton.

Pleurotomaria obesa, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 11, p. 79.
Great Oolite. [8178] Minchinhampton.

Pleurotomaria pagodus, J. A. E. Deslongchamps, var. **depauperata**, Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 9, p. 77.
Great Oolite. [8236] Minchinhampton.

Pleurotomaria recondita, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlv., f. 7, p. 106.
Great Oolite. [8179] Bussage.

Pleurotomaria scalaris, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc. 1851, pl. x., f. 14, p. 77.
Great Oolite. [8180] Minchinhampton

Pterocera ignobili s Morris and Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iii., f. 14, p. 14.
Great Oolite. [8418] Minchinhampton.

Purpuroidea galbra, Morris and Lycett, **T.**
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iv., f. 5, 5*a*, 6, 6*a*, p. 28.
Great Oolite. [8399, 8400] Minchinhampton.

Purpuroidea insignis, Lycett. **T.**
J. Lycett, "Cotteswold Hills," 1857, pl. vii., f. 8*a*, *b*, p. 124; Mon. Pal. Soc. Suppl., 1863, pl. xxxi., f. 2, 2*a*, p. 6.
Great Oolite. [8407] Minchinhampton.

Purpuroidea Moreausia, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. iv., figs. 1, 1*a*, 2, 3, 3*a*, p. 27; **P. Morrisii,** *Ibid.*, 1855, p. 148; **P. Morrisea,** J. Lycett, Suppl., 1863, p. 121.
Great Oolite. [8404–8406] Minchinhampton.

Purpuroidea nodulata (Young and Bird).
J. Lycett, Ann. Mag. Nat. Hist., 1848, vol. xi, p. 250, 251.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., figs. 2, 3, p. 28.
Great Oolite. [8402, 8403] Minchinhampton.

Purpuroidea nodulata (Young and Bird).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. v., f. 1, 1*a*, p. 28.
Great Oolite. [8401] Minchinhampton.

Rimula Blotii, (J. A. E. Deslongchamps).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 3, 3*a–c*, p. 87.
Great Oolite. [8173] Minchinhampton.

Rimula clathrata (J. de. C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. viii., f. 1, 1*a–c*, p. 86.
Great Oolite. [8174] Minchinhampton.

Rissoa (Hydrobia) conulus (Robertson, MS.) Forbes. T.
E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 12, p. 110.
Estuary Shales. [8645] Loch Staffin, Skye.

Rissoa ? exigua, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 11, p. 9.
Great Oolite. [8297] Bussage.

Rissoa ? tumidula, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 13, p. 98.
Great Oolite. [8296] Bussage.

Rissoina acuta (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 9, p. 53.
Great Oolite. [8293] Minchinhampton.

Rissoina cancellata, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 12, 12*a*, p. 53.
Great Oolite. [8295] Minchinhampton.

Rissoina duplicata (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 10, p. 52.
Great Oolite. [8294 Minchinhampton.

Rissoina ? lævis (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 16, p. 54.
Great Oolite. [8298] Minchinhampton.

Rissoina Witchelli, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliv., f. 12, p. 18.
Great Oolite. [9024] Minchinhampton.

Solarium bathonicum, Lycett. T.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlv., f. 27, 27*a–c*, p. 23.
Great Oolite. [8302] Bath.

Solarium disculum, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 25, 25*a*, *b*, p. 70.
Great Oolite. [8303, 8304] Minchinhampton.

Solarium polygonium, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 24, 24*a*
Great Oolite. [8300, 8301] Mus

Solarium varicosum, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 23, 23*a*
Great Oolite. [8299] Mus

Stomatia ? (Megastoma) Buvignieri, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 3
Nerita, J. Lycett, Suppl., 1863, p. 121.
Great Oolite. [8161] Mus

Trochotoma acuminata, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 20, p. 8
Great Oolite. [8175] Mus

Trochotoma conuloides, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 16, p. 8
Great Oolite. [8183] Mus

Trochotoma discoidea (F. A. Roemer).
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 10, 10*a*
Great Oolite. [8184, 8185] Mus

Trochotoma extensa, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 19*a*, *b*,
Great Oolite. [9013] Mus

Trochotoma obtusa, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 15*a*, *b*,
Great Oolite. [8186] Mus

Trochotoma tabulata, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 17, 17*a*
Great Oolite. [8187] Mus

Trochus Dunkeri, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 3, 3*a*, p.
Great Oolite. [8226] Mus

Trochus Ibbetsoni, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 4, 4*a*, p.
Great Oolite. [8227] Mus

Trochus obsoletus, F. A. Roemer.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 1, 1*a*,
Great Oolite. [8228] Mus

Trochus plicatus, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. x., f. 8, 8*a*, p.
Great Oolite. [8231] Mus

Trochus spiratus, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xiii., f. 6, 6*a*
Great Oolite. [8230] Mus

Trochus squamiger, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 34, 34
Great Oolite. [8229] Mus

Turbo capitaneus, Goldfuss.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 33, 33*a*
Great Oolite. [9018] Mus

Turbo elaboratus, Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 27, p. 64.
Great Oolite. [8233] Minchinhampton.

Turbo Gomondei, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 5, p. 66.
Great Oolite. [8235] Minchinhampton.

Turbo hamptonensis, Morris and Lycett.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 30, 30*a*, *b*, p. 64.
Great Oolite. [8232] Minchinhampton.

Turbo obtusus, J. de C. Sowerby.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xi., f. 9, 9*a*, p. 66.
Great Oolite. [8237] Minchinhampton.

Turbo pygmæus, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 29, 29*a*, p. 65. **Brachytrema**, J. Lycett, Suppl. 1863, p. 122.
Great Oolite. [8413] Minchinhampton.

Turbo Sharpei, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. ix., f. 28, 28*a*, p. 65.
Great Oolite. [8234] Minchinhampton.

Umbrella ? hamptonensis, Morris and Lycett. T.
Morris & Lycett, Mon. Pal. Soc., 1851, pl. xii., f. 12, 12*a*, p. 95.
Great Oolite. [8203] Minchinhampton.

Valvata præcursor, Tate. T.
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 9, p. 348.
Infra-Oxfordian Estuarine. [8596] Prince Charles's Cave, Portree.

CORNBRASH.

Chemnitzia vittata (Phillips).
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxi., f. 10, p. 14.
Cornbrash. [8432] Scarborough.

CORALLIAN.

Alaria bispinosa (Phillips).
W. H. Hudleston, Geol. Mag., vol. vii., 1880, pl. xvii., f. 6*a*, *b*, p. 533.
Calcareous Grit. [8456] Pickering, Yorkshire.

Dentalium entaloides, J. A. E. Deslongchamps.
Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxi., f. 11, p. 28.
Lower Calcareous Grit. [8433] Scarborough.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

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OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

AND

MUSEUM OF PRACTICAL GEOLOGY

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1904.

INTRODUCTION.

By J. J. H. TEALL, M.A., D.Sc., F.R.S., Director.

In England and Wales field-work has been carried on in four districts, Cornwall, South Wales, the Midlands, and the neighbourhood of Oxford. In the three first mentioned districts the work of previous years has been continued. The fourth district has been temporarily added for the purpose of issuing a special map with Oxford as a centre.

In Scotland progress has been made with the original survey of the Highlands and with the revision of the Carboniferous rocks of the Midland Valley; while in Ireland the re-survey of the drifts in the neighbourhood of Limerick has been completed. Following the practice of previous years I now propose to refer to some of the features of the recent work, taking the formations as far as possible in chronological order.

Highland Metamorphic Rocks.

The oldest rocks with which we have had to deal are situated in the Highlands of Scotland. North of the Caledonian Canal work has been carried on in the high ground drained by the Meig, the Conon, the Orrin and the Farrar, which flow east to the Moray Firth (Sheet 82.)

About ten years ago Dr. Peach first broke ground in this region, separating gneisses of Lewisian type from the schists and granulites of sedimentary origin belonging to the Moine series. Much work has since been done in areas composed of Moine rocks, and, as pointed out in last year's Summary, it is now generally recognised that two distinct types of sediment occur; an arenaceous type represented by quartzo-felspathic granulites, and a muddy or argillaceous type characterised by an abundance of mica, and frequently referred to as garnetiferous mica-schist or muscovite-biotite-gneiss (pelitic gneiss). Impure calcareous types are also represented, but they are entirely subordinate

Highland Metamorphic Rocks.

to the two types above referred to. In tracing the boundaries between the Moine group and the gneisses of Lewisian type Dr. Peach detected a marked discordance, which he attributed to the fact that the Moine sediments had been laid down unconformably on rocks of the age of the Lewisian gneiss. During the past year work has again been commenced in this area, and additional evidence of discordance between the sedimentary schists and the rocks referred to the Lewisian gneiss has been obtained. In the account which follows it is clear that the officers engaged in the survey are inclined to accept Dr. Peach's view as to the meaning of this discordance, although they point out that certain quartz-biotite-granulites associated with gneisses of Lewisian type are undistinguishable in hand specimens and under the microscope from typical Moine granulites. The problem here raised is one of so much importance from the point of view of the structure and geological history of the Highlands that its full discussion may well be allowed to stand over until the entire area has been surveyed.

South of the Caledonian Canal in the Findhorn area (sheet 84), where work has also been carried on during the year, the rocks belong, for the most part, to the two types of the Moine series and to later plutonic intrusions. Portions of the pelitic gneiss have been so impregnated with granitic material that the resulting rock resembles a coarsely-foliated granite. Gneisses of Lewisian type are, as a rule, absent from this region, but south-east of Lochindorb there is a zone of hornblende-gneiss which possesses many of the features of these rocks. It must, however, be remembered that many different types are included under the general term Lewisian gneiss, and that some of these types have been closely simulated in rocks of much later date, as, for example, in the banded gabbros of Tertiary age in Skye.

The newer plutonic intrusions of this area include diorites or epidiorites, quartz-diorites, biotite-granites, muscovite-biotite-granites and pegmatites.

Passing now to the other side of Scotland we have to note the results obtained in the area south-east of Loch Linnhe. In the Glen Creran district, north-west of the granite massif of Ben Cruachan, the metamorphic rocks of sedimentary origin consist of quartzite, limestone, black-schist and certain grey phyllites which are recognised as belonging to the Ardrishaig group. Two bands of limestone and two of black-schist have been mapped, making six distinct sedimentary horizons. The quartzite, which is often pebbly, and which is correlated with that of Schichallion in Perthshire, comes in contact with the Ardrishaig phyllites, the black-schist and the two limestones, as if unconformable to them. Similar evidence of the existence of an unconformability at the base of a quartzite in the Ballachulish and Glencoe area, and also in the Knapdale area, was referred to in last year's Summary.

Much additional information as to the later igneous intrusions and as to their effects on the different members of the Highland

sedimentary series has been obtained. New exposures of augite-diorite and kentallenite have been discovered, and augite-diorite has been observed to pierce the Ben Cruachan granite, thus proving it to be of later date, and furnishing an apparent exception to the general rule that, in a series of connected plutonic intrusions, the more basic rocks are the earlier. Highland Metamorphic Rocks.

To the north-east of the Ben Cruachan mass dykes occur in such numbers that, over a considerable part of the area, they form half the rock of the country. They vary in character, and the more basic are in general the later. This is now recognised as the normal sequence in minor intrusions belonging to the dyke phase.

Ordovician rocks have been traced westward from Caermarthen in order to complete the series of one-inch maps relating to the South Wales Coal Basin. The subdivisions recognised are practically identical with those established in the Haverfordwest district by Messrs. Marr and Roberts, and in the Caermarthen district by the Misses Crosfield and Skeat, as explained in last year's Summary (page 32). The detailed mapping of these sub-divisions has brought out very clearly the structure of the district. It consists of a series of anticlines and synclines, whose axes trend a little south of west, and which have been pushed from the north and overfolded towards the south. In the course of the work the occurrence of Tetragraptus beds was recognised in an area where they had not previously been noted. Lower Palæozoic.

Ordovician and Silurian rocks have engaged the attention of the Survey in Cornwall. Mr. Upfield Green's discovery of Silurian fossils at Porthluney has been followed up by the discovery of other fossils belonging to the same general period. These fossils occur in detached blocks in a crush-breccia which, according to Mr. Reid, marks the position of an important overthrust. Mr. E. T. Newton suggests that among these blocks may be found representatives of various missing strata between the Ordovician and the lowest Devonian.

Volcanic rocks of Lower Old Red Sandstone age with some intercalated sediments have been surveyed in the West Highland region, and a definite sequence of about 1,800 feet has been observed in one locality. The lowest group consists of 500 feet of andesitic lava-flows and ash-beds, the middle group of 300 feet of breccias and ashy sandstones, and the upper group of about 1,000 feet of trachytic rocks which are not easily separable into lavas and tuffs in consequence of the fragmental aspect of many of the lavas. Additional evidence of the unevenness of the floor on which the volcanic rocks were accumulated has been obtained, and from evidence seen on Beinn Ceitlein it is inferred that the slope in that locality was about one in two. Devonian.

A narrow outlier probably belonging to the Middle or Orcadian division of the Old Red Sandstone has been mapped in the valley of the Findhorn. It is bounded by two parallel faults.

Devonian. A re-examination of the volcanic rocks of Lower Old Red Sandstone age in the Pentland Hills has resulted in the recognition of many new types, ranging in composition from basalts to rhyolites.

In the Edinburgh district the remains of *Holoptychius nobilissimus* have been found in the sandstones underlying the dolerite of Salisbury Craigs and also in those of Craigmillar, thus proving the Upper Old Red Sandstone age of rocks which have hitherto been regarded as Carboniferous. Upper Old Red Sandstone has also been surveyed in the neighbourhood of Dunbar and in the Strathblane area.

Work on the Old Red Sandstone has also been done in South Wales. The unconformability at the base of this formation is strongly marked in the area surveyed during the year where a basal conglomerate may be often seen resting at a gentle angle on upturned strata of Ordovician age. On the northern side of the Pembrokeshire coalfield the strata appear to belong wholly to the lower division; but on the southern side there are some quartzitic sandstones and breccias associated with red marls and greenish shales which may prove to be of Upper Old Red Sandstone age.

Carboniferous. Carboniferous rocks have been surveyed in South Wales, the Midlands, and in Scotland. Much interest attaches to work on the Carboniferous limestone at present, in consequence of the recent researches by Dr. A. Vaughan on the zonal distribution of corals and brachiopods in the limestone of the Bristol district. Dr. Vaughan very kindly visited the area in which work is now going on in South Wales and rendered assistance to our officers in the identification of the zones which he has established. Some account of the results already obtained, which are of considerable interest, will be found in the following pages. In view of this work careful attention has been paid to the vertical distribution of corals in the Carboniferous limestone of Derbyshire, and although only a small portion of this formation, both as regards thickness and area, has been examined, it has been clearly established that certain corals are characteristic of certain horizons, though to what extent these zones will be found to hold good when a larger area is examined, cannot at present be stated.

Much work has been done on the Carboniferous rocks of the Midland Valley of Scotland, in West Lothian and Peebles, in East Lothian and Haddington, in the Glasgow district, and in the District of Bo'ness, Linlithgow, and Bathgate. In East Lothian and Haddingtonshire additional information has been obtained as to the sequence and tectonic relations of the contemporaneous and intrusive igneous rocks which are associated with the Calciferous Sandstone and as to the structure of the Carboniferous Limestone area in which the Edge coals occur.

In the Glasgow district the volcanic rocks of the Kilpatrick Hills and Campsie Fells which are associated with the Calciferous Sandstone series have been sub-divided, and this work has led

to the determination of the positions of several large faults which break up the volcanic plateau into sections. The coarse sandstone and conglomerates which rest on the volcanic rocks have been proved to underlie the Hurlet Limestone and have, therefore, been removed from the Carboniferous limestone and classed with the Calciferous sandstone. The upper boundary of the Carboniferous limestone series has also been altered, and, as now drawn, is immediately below the horizon of the valuable fireclays that are extensively worked in the Garnkirk and Castlecary region to the east. In the Bowness and Linlithgow district much additional information has been obtained with reference to the limestones, coals, and igneous rocks belonging to the Carboniferous limestone series. In the course of the revision of the Carboniferous rocks of Scotland the records of a very large series of borings and sinkings are being accumulated. These are of great local importance, and they are being arranged and catalogued so as to be readily available for reference. Carboniferous.

In the course of the re-survey on the six-inch scale of the Coal-measures of the Derbyshire coalfield special attention is being paid to the zonal distribution of both plants and animals, and some particulars of the recent work in this direction are given in the following pages. The examination of an extensive series of Lamellibranchiata proves that, in the main, the vertical distribution of these fossils agrees with that established by Dr. Wheelton Hind for North Staffordshire.

The search for coal beneath the Triassic rocks of the Midlands which has been going on for many years and is likely to continue, has brought into great prominence the importance of an accurate knowledge of the sub-divisions of the upper unproductive measures. Mr. Gibson has paid special attention to this question and he has prepared a summary of the results obtained up to the present. This is printed in an appendix.

Rocks of Triassic age have been surveyed in the Midland district. In the Nottingham area the boundary line between the Waterstones and the Keuper Marls has been drawn at a somewhat higher horizon than formerly, but as the passage from the one formation to the other is gradual, the actual dividing line is in any case a more or less arbitrary one. Trias.

In the Vale of Belvoir the tea-green marls, formerly classed with the Rhætic, have now been relegated to the Keuper, and this has necessitated the drawing of a new line for the base of the Rhætic.

Some necessary changes have also been made in the course of the line separating the Lias from the Rhætic. A band of ferruginous limestone characterised by *Gryphœa arcuata* has been traced in the Lias and the positions of several other bands of limestone, forming minor and often impersistent escarpments, have been recorded. Lias.

Jurassic and Cretaceous rocks have been examined in the neighbourhood of Oxford. The most interesting result of the work in this area is the definite recognition of the Portlandian age of the Jurassic and Cretaceous.

iron-stones of Shotover containing marine fossils. The occurrence of these fossils has long been felt to be a difficulty in the way of accepting the view that the Lower Cretaceous iron-sands of Shotover and Brill are of purely fresh-water origin. This difficulty is now removed.

Pleistocene and Recent.

In all districts where field-work has been going on special attention has been paid to the nature and distribution of the different types of the superficial deposits which determine over large areas the character of the soils, and throw important light on the physical conditions of the glacial and later periods. Special attention may be directed to the work in the Findhorn area and in the country around Limerick. The phenomena of erosion and deposition which accompanied the retreat of the Findhorn and Spey glaciers have been worked out in considerable detail, and the natural history of that district, so far as the later stages of the glacial period are concerned, is recorded, in outline, in the following pages.

I.—ENGLAND AND WALES.

1.—FIELD-WORK.

The ground to be surveyed was arranged in four areas as follows :— Mr. Woodward.

1. Midland district under Mr. C. Fox-Strangways (until his retirement at the end of July).
2. Oxford area, under Mr. H. B. Woodward.
3. Southern district under Mr. Clement Reid.
4. South Wales district under Mr. A. Strahan.

In the *Midland district* work was carried on in Sheet 112 (Chesterfield) over a portion of the Derbyshire coal-field ; and in sheets 126 (Nottingham) and 142 (Melton Mowbray) over the Triassic areas bordering the Trent Valley, and the Lias of the Vale of Belvoir.

The district memoir on the Leicestershire and South Derbyshire coal-field has been completed. A new edition of the memoir on the Geology of Stoke-upon-Trent has been called for, together with a new edition of the map, sheet 123 without Drift : these have been put in hand.

Much information was obtained with reference to deep borings from an examination of cores at Astley, Heaton, Manchester, Claverley, Desford, and Lullington. (See Appendix I, p.150).

In the *Oxford area*, field-work supplementing that done by the late Mr. J. H. Blake was carried on in parts of sheets 236, 237, and 253, with the view of preparing a special geological map with Oxford as a centre.

In the *Southern district* the survey of the Scilly Isles (sheets 357 and 360) has been completed, and work has been carried on in sheet 347 (Bodmin and St. Austell), in the adjoining area to the north, sheet 336 (Camelford), also in sheet 353 (Mevagissey).

All the available mine-plans relating to Cornwall have now been examined and the information has been recorded on the six-inch maps. Much additional information relating to the mining has also been obtained personally on the ground.

The memoir on sheet 346 (Newquay) has been completed.

In the *South Wales district* the mapping of the main portion of the coal-field has been completed, and the field-work has been carried westwards in sheet 229 (Carmarthen), 228 (Haverfordwest), and 245 (Pembroke and Tenby), including portions of the Pembrokeshire Coal-field.

Examinations have been made of the following new railway-cuttings : (1) Great Western extension between Castle Cary and Langport ; (2) Great Western branch between Clarbeston Road and Letterston near Fishguard ; (3) Great Central between Uxbridge and Loudwater, and between Princes Risborough and Wotton Underwood ; (4) and Tube-railways under London.

1. Midland District—Derbyshire, Nottinghamshire, and Leicestershire.

Mr. C. Fox-Strangways, District Geologist (*until July*).
Mr. B. S. N. Wilkinson
Mr. W. Gibson, B.Sc.
Mr. C. B. Wedd, B.A.
Mr. W. B. Wright, B.A.
Mr. R. L. Sherlock, B.Sc.
} Geologists.

The work of the past year has lain in the Carboniferous rocks in the neighbourhood of Matlock and Ashover and in the Mesozoic, Glacial, and Recent strata around Nottingham and Bingham.

CARBONIFEROUS.

Carboniferous Limestone.

Mr Wedd. In the Carboniferous Limestone a zonal sub-division by corals and brachiopods has been attempted on the lines on which Dr. Arthur Vaughan has worked in the south-west of England; so far as it is possible to do so in the limited thickness of limestone seen here. This thickness may be estimated at not much more than 500 feet, exclusive of toadstone, in the ground yet surveyed.

The corals have been found more promising than the brachiopods for the purpose of sub-dividing the limestone. The work is not yet finished, but as far as it has gone in the district of Matlock and Bonsall, it is found that certain corals are characteristic of certain horizons. The results so far obtained may be summarized briefly as follows, the horizons being given in descending order, and the thicknesses taken from previously published sections.*

Blue cherty limestones (about 70 feet): Fasciculate species of *Lithostrotion* (including chiefly *L. irregulare* and *L. junceum*), *Diphyphyllum* sp., *Aspidophyllum* ? sp., and in the lower part *Cyathophyllum regium*.

Zaphrentis sp. also occurs. *Productus giganteus*, *P. semireticulatus*, *Spirifera striata* all abundant.

White and light-coloured limestones (about 100 feet): the same fasciculate species of *Lithostrotion*, *Cyathophyllum regium*, *Productus costatus*, *P. punctatus*.

Horizon of highest Toadstone.

White and light-coloured limestones (about 150 feet): the same fasciculate species of *Lithostrotion*, *Cyathophyllum regium* (in upper part), *Cyathophyllum parricida*, *Dibunophyllum* sp. (especially in lower part), *Lonsdaleia floriformis*.

Horizon of second Toadstone.

White and light-coloured limestone (thickness not certain): the same fasciculate species of *Lithostrotion* much less abundant; *Lithostrotion Phillipsi*; comparatively few coral-bearing beds found.

White and light-coloured limestone (thickness not certain): *Lithostrotion irregulare* (rarely), *L. Phillipsi*, massive species of *Lithostrotion* (including *L. basaltiforme*), *Campophyllum* sp., *Cyathophyllum* large simple sp., *Lonsdaleia floriformis ?* (occasionally). *Productus giganteus* (of both forms), *P. semireticulatus*, *Spirifera striata* all still abundant.

* "Geology of the Carboniferous Limestone, etc., of N. Derbyshire": (*Mem. Geol. Surv.*), Ed. 2. p. 22., 1887.

Only a few of the more important species are given above. The limestone of the district is very rich in corals, of which about forty different forms have been obtained. On the other hand the brachiopod fauna seems to be poor in species, though a few of these species are extremely common. *Productus giganteus* (both the broad alate and the short-winged forms) is particularly numerous in the blue cherty limestone, but is found abundantly at several horizons down to the lowest beds examined. *P. semireticulatus* occurs throughout at different levels. So far *P. costatus* and *P. punctatus*, locally abundant, have been found only in the limestone without chert above the highest toadstone, but it remains to be seen whether the vertical range of these brachiopods is really so restricted. *Spirifera striata* occurs frequently throughout. Mr. Wedd.

Dolomitic limestone appears at several horizons, and the silicified limestone chiefly seen in this district on the north-east side of Bonsall has been found by Mr. Arnold-Bemrose * to occur irregularly in other parts of the sequence.

In the clearly dissected anticline of Ashover between 150 and 200 feet of the upper beds of Carboniferous Limestone are exposed. The lower 60 feet or so is a massive white limestone with little or no chert. The rest is of a blue colour and contains abundant chert. Thick beds of *Productus giganteus* are common in the cherty portion. On the slope north-east of Butts Pasture the limestone contains a thick vein of brecciated chert, calcite, and fluor spar, forming a marked ridge striking north-west and south-east. It appears to have a steep dip to the north-east. Mr. Wright

IGNEOUS ROCKS.

Though the mapping of the igneous rocks of the Matlock district has not yet been completed, the outcrop of the highest bed of toadstone has been traced some distance further west than is indicated on the published map. It has also been followed east of the Derwent under the limestone escarpment of Lovers' Walks, Matlock Bath. Mr. Wedd.

In the Ashover district we have nothing further to add to the detailed description of the toadstone given by Mr. H. H. Arnold-Bemrose.† Mr. Wright

Upper Limestone Shales.

Few opportunities have occurred of examining any but the lowest beds of this series, the thickness of which up to the lowest massive grit is about 400 feet. ‡ A good section in the cutting at the south end of the tunnel at Cromford Station exposes the lowest beds. Here, and in the immediate neighbourhood, they consist of black and blue shales with several bands of Mr. Wedd.

* *Quart. Journ. Geol. Soc.* vol. liv. p. 170.

† *Quart. Journ. Geol. Soc.* vol. l. pp. 639–641, 1894.

‡ "Geology of the Carboniferous Limestone, etc., of N. Derbyshire": (*Mem. Geol. Surv.*). Ed. 2, p. 75.

Mr. Wedd. compact blue limestone up to two feet in thickness, and lines of bullions of the same material. The shales contain *Glyphioceras Phillipsi*, *Posidonomya*, *Posidoniella*, and *Pterinopecten papyraceus*. At the north end of the same tunnel, south of Matlock Bath Station, the basement beds are clearly seen above the massive limestone, but are inaccessible. Here their junction with the limestone is sharply marked. No definite beds of limestone appear in the lower shales, though one or two layers a few inches in thickness were noticed. Between Matlock and Wensley it has been necessary to modify the mapping of the base-line of this series.

Above the shale-series a fine-grained white grit of considerable thickness runs round the west flank of Riber Hill, Matlock, but has not yet been traced into continuity with either of the grits below the Upper Kinderscout Grit of the country south of Cromford.

Millstone Grit.

The Upper Kinderscout Grit forms the higher escarpment of Riber and the lower one of Matlock Bank, the two outcrops running down eastward and uniting in the intervening valley at Tansley. South-eastward this grit has been traced in continuity with that of the district included in Sheet 125. In the Matlock district it is of the same character as further south and presents no features of especial interest.

A series of blue shales with minor grit-bands succeeds the Kinderscout Grit as usual. At the bottom of this shale the coal, which has been traced at intervals southward beyond Belper, has been met with lately near the south end of the tunnel of the Derwent Valley Waterworks on Matlock Bank, where it is not much more than one foot thick.

Above these shales the "Third" Grit, or lowest member of the Middle Grit Group, represented by a massive rock, fine-grained on the whole, as it is further south, but with a tendency to become rather coarser northward, makes the plateaux of Matlock, Tansley, and Dethick moors, and usually ends in a sharp escarpment. It is continuous with the corresponding grit of Lea and Whatstandwell.

In the overlying shales a marine bed containing *Lingula mytiloides* was noticed east of Lea.

Mr. Wright. To the north-east of Ashover between Ashover and Alton four grits can be seen, but on the east and south-east only three. These appear to suffer some displacement in crossing the valley of the Amber, but can be traced to the south of it on the eastern slopes of Ashover Hay. The absence of the First Grit or Rough Rock along this margin of the anticline may be due to the Trinity Chapel Fault.

Coal-measures.

A seam of coking coal has been worked to the south-east of Alton. The depth and other details have not yet been ascertained, but fossils, similar to those got by Mr. Wedd in the brickpits at Bullbridge, Ambergate, have been obtained from the tip heap, and it is hoped that their distinctive character may enable this seam to be traced over a considerable area. Mr. Wrig

About one mile north of Alton a very pronounced feature is formed by Coal-measure sandstones which are regarded by Mr. Gibson as the equivalent of the Elland Flags. The strata are underlain by a considerable thickness of black shales containing a flaggy sandstone of minor importance and a little lower down a very small coal seam.

There appears to be another sandstone between this and the First Grit.

In connexion with the survey of the Derbyshire Coal-field, much work beyond the actual mapping has been done in the examination of new sections afforded by the sinking of shafts, underground explorations, and recent railway cuttings. The collection of fossils both of the flora and fauna has also been systematically undertaken as far as time permitted. We now propose to give some of the main results obtained; with especial reference to the problem as to how far the Coal-measures are capable of being zoned by means of the fossils. Mr. Gibs

The additions that have been made to the known flora have not been numerous; but the study of the entire flora has been undertaken by Mr. R. Kidston. So far not a single plant, such as *Pecopteris arborescens*, indicative of the Upper Coal-measure age of any of the measures below the Top Hard (Barnsley Seam) has been met with. On the contrary the plants collected from the beds between the Black Shale Coal (Silkstone) and Top Hard Coal are such as are associated with the Middle Coal-measures of other coal-fields. The plant remains above the Top Hard up to the highest horizon exposed at the surface indicate the same age. Few plants have been collected from below the Black Shale Coal, as exposures are very limited.

The results obtained from an extensive collection of the lamellibranchiata are as follows:—

So far *Anthracomya Phillipsi* has only been found high up in the sequence and never in that portion of which the plant remains indicate a Middle Coal-measure age. These high measures never appear at the surface within the area at present examined, but have been passed through in sinking the shafts of the Gedling Colliery and in the boring at Thurgarton.

Above the Top Hard Coal we have not seen a single specimen of *Carbonicola robusta* or an example of *Naiadites*. On the other hand *C. robusta* has been found to be characteristic of the shale bands associated with the lowest seams—viz., between the Kilburn and Deep Hard Coals. *Naiadites* indicates a somewhat higher

Gibson. horizon; while *Carbonicola aquilina* is universally met with in a grey shale a few feet above the Top Hard Coal, but the same shell also occurs above a seam, known at Gedling as the High Hazles, which occurs 256 feet above the Top Hard Coal.

On comparing these results with those worked out by Dr. Wheelton Hind in North Staffordshire it will be seen that on broad lines the zones in Derbyshire agree with those in Staffordshire. Up to the present time, however, no specimens of *Anthracomya adamsi*, *A. Williamsoni*, or *A. pulchra*, which according to Dr. Hind are confined to definite horizons in Staffordshire have been met with.

The marine beds associated with the Coal-measures have been mentioned in the Summary for 1902. No additional horizons or fresh localities have been discovered. It is therefore uncertain how far these bands are of service in fixing horizons among the Coal-measures of Derbyshire and Nottinghamshire.

TRIAS.

Sherlock. The examination of the ground occupied by Triassic rocks around the city of Nottingham has resulted in the addition of some faults and the modification of others shown on the published map. The boundary between the Waterstones and the red Keuper Marls above them has been taken in places at a somewhat higher horizon than in the previous map. Although there is a gradual lithological passage between the two formations a feature can generally be followed, which may be taken as the boundary line.

Bunter.

The examination of these rocks in connection with the survey of the Drifts has not brought to light any facts needing especial mention.

The Lower Mottled Sandstone of a Central Midland type is seen at Spring Close, Lenten, at Bobber's Mill, and at Two Mile Houses, Basford, all within the city of Nottingham. When it again appears at Bulwell, and from there northwards, the red and yellow mottling which gives it its name has disappeared and it has become a fine-grained red sand-rock.

Keuper Sandstones.

Wilkin- This sub-division, consisting of thin, flaggy, soft, red sandstones, with much intercalated marl, crops out in the Dover Beck Valley, where the beds lie nearly horizontally.

Sherlock. The conglomerate which has been exposed at the base of the Keuper in various excavations near the city of Nottingham is, at present, only visible at Sneinton, where the Great Northern suburban line crosses the line from Nottingham to Newark Road.

Keuper Marls.

Mr. Sherlc

The Keuper Marls around Nottingham form a curious flat table-land most marked in the Mapperley Plains. If this feature has been caused by the outcrop of a definite bed of hard rock, this bed is often no longer in existence since the flat is occupied in part by sandstone and in part by red clay. The plain is deeply trenched by "Dumbles," with the Waterstones exposed at the bottom, as at Lambley.

A definite horizon of clay with gypsum has been traced for some distance and is valuable for calculating the amount of throw of the faults which occur in the Colwick area.

Rhætic Beds and Lias.

Mr. Wrig

The Rhætic and Lias formations which crop out in the Vale of Belvoir have been examined for a short distance between Elton and Bottesford. The most conspicuous feature of this district is the escarpment, which crosses the country in a general N.E.-S.W. direction. The face of the escarpment is composed of the Rhætic Beds (White Lias and Black Shales), and the boundary of the Lower Lias is usually a short distance down the dip slope. This boundary has been altered in some places, where the new evidence obtained seemed to warrant it, and an entirely new boundary line has been drawn for the base of the Rhætic. The tea green marls at the top of the Keuper, originally mapped with the Rhætic Beds, have been separated, and a massive band of gypsum at a slightly lower horizon has also been traced for some distance.

A smaller escarpment is formed some distance to the south-east in the neighbourhood of Redmile and Muston by the outcropping of some hard ferruginous limestone beds in the Lower Lias. The soil above this "ironstone" band is often of a bright red colour, and much lighter in texture than that derived from the weathering of the adjacent Lower Lias clays and shales. It is characterised by a great abundance of *Gryphæa arcuata*, the shells of which are strewn about the fields in thousands.

Several bands of limestone both above and below this zone, which form minor and sometimes impersistent escarpments, have also been traced.

GLACIAL.

Mr. Stran ways.

In the Summary of Progress for 1903 (p. 16) it was stated that large areas in southern Derbyshire are free of Glacial deposits. Within the area surveyed during the year isolated patches of gravels and Boulder-clay have been met with which represent various stages in the glaciation of the country. It is requisite, however, that much larger areas be examined before it would be safe to venture on an attempt to piece together the scattered information already obtained.

. Wedd. Over the high ground in the neighbourhood of Matlock several patches of Boulder-clay have been mapped. These are found to occur chiefly on relatively high ground, in hollows or on flats under the lee of still higher ground to the north. The Boulder-clay in the shale-and-grit district is usually a tough blue clay when unweathered, with many boulders of local rocks, chiefly grit, chert, and limestone, the last-named often ground or striated.

A large patch of Boulder-clay covers the southward slope of the high ground between Dethick and Tansley. The synclinal hollow in the Kinderscout Grit of Riber Hill, Matlock, is also filled with Boulder-clay. Similar Drift has been cut through above the Kinderscout Grit at the south-east end of the tunnel of the Derwent Valley Waterworks on Matlock Bank. Drift also occurs in the upper part of Tansley Brook at Tansley. Within the limestone area the flat hollow south of Bonsall Moor contains Drift. There is also a small mass of Boulder-clay at the south end of Northern Dale, Snitterton. The significance of this will be discussed below.

·. Wright. Bath Lane, which runs north from Ashover, passes over a flat area of stiff blue boulder-clay weathering brown and containing well-scratched boulders of shale and grit. Sections four or five feet deep may be seen along the roadside.

In the Vale of Belvoir the low-lying Keuper Marl ground is extensively, but thinly, covered by Boulder-clay, and large areas are occupied by spreads of alluvium. The Boulder-clay, which seems to average a few feet in thickness, consists of flints and quartzite pebbles embedded in a matrix of marl.

.Sherlock. Drift attains a considerable development south of the Trent. The prominent feature of Wilford Hill has a thick covering of Drift sand and gravel, and the feature extends with interruptions, eastwards in the direction of Cotgrave, where it passes out of the area at present surveyed. In the southwest corner of West Bridgford parish an exposure of Drift, similar to that seen in Annesley Park, has been found, which is of interest as being the most southerly point where this Drift has as yet been seen.

The prominent ridge of sand and gravel at Bestwood on which the Lodge is built is made of Drift.

A ridge of gravel runs from West Bridgford (where it can be seen to commence in the slight cutting for the extension of Musters Road) through Gamston Village and south of the Upper Radcliffe Road, becoming rapidly higher and wider as it is followed north-eastwards. In the past the water of the small southern tributaries of the Trent have been ponded back behind the ridge into a series of meres. Their sites are indicated by flats covered by stiff black loam breaking with a starchy fracture and crowded with small freshwater shells. One of the lakes has its centre at the junction of Edwalton, West Bridgford, and Holme Pierrepont parishes, and another and larger one is traversed by the Thurlbeck. The gap through which the Edwalton Lake drained is now occupied by the Nottingham and Grantham Canal.

POST GLACIAL AND RECENT.

While but little evidence has been found to throw further light upon the formation of the characteristic limestone-dales in general, the formation of one of the smaller dales (Northern Dale, Snitterton) can be traced with some degree of certainty to late-Glacial or early post-Glacial denudation. A mass of Boulder-clay blocks a dry valley running eastward to Snitterton, and unites the escarpment of the blue cherty limestone with the dip-slope of the lower limestones dipping north-east. It lies as high as the summit of the western part of the escarpment through which Northern Dale is cut in the direction of dip. The Drift has evidently diverted an older eastward drainage and caused it to flow north-eastward, excavating a deep dale through the escarpment of the cherty limestone. But this mode of origin is probably exceptional. Mr. Wedd.

A noticeable characteristic of the limestone-dales is that they are often bounded by a steep or vertical escarpment on one side and by a much less abrupt slope on the other. As far as observation goes at present, this characteristic is connected with the dip of the strata, as of course might be expected. It seems to be only where the dale runs approximately with the strike that a less abrupt slope marks that side in which the beds dip towards the dale, the other side with outward dip forming a steep escarpment. The Derwent Valley at High Tor and Matlock gives examples of this, though in the former instance a minor escarpment in the general slope on the west side is produced by an underlying outcrop of toadstone.

Besides the river-alluvium of the district, which presents no features of especial interest, the chief recent deposits are those of calcareous tufa, principally at Matlock Bath. This tufa makes a broad terrace-like platform at the foot of the dip-slope of the limestone at Matlock Bath on the west side of the Derwent, opposite Lovers' Walks. Its formation is attributable to deposition by the warm springs before the latter were confined in artificial channels.* The considerable elevation of this deposit above the river may be connected with the once higher level of the latter; and it may be noted that immediately south of this platform of tufa, a constriction of the valley and a weir, under which limestone is visible in the river-bed, probably denote the denudation of a rock-barrier at that spot and the consequent deeper excavation of the channel above it. If this be so, the deposition of tufa by the springs would take place at a higher level than would otherwise be the case—perhaps at the margin of slack water held up by the barrier.

North of the Trent there is evidence that the streams were much greater in the past than at the present time. Numerous deep winding dry valleys with flat gravelly bottoms are found in Mr. Sherlock

* "Geology of the Carboniferous Limestone, etc., of N. Derbyshire," Ed. 2, p. 166.

[r.Sherlock. Sherwood Forest as far north as Blidworth, beyond which they have not been followed. Though now quite dry they evidently represent the sites of old river channels. The high roads frequently follow these valleys; thus the Ollerton Road from the foot of Cockpit Hill to the Dover Beck lies in one.

A gravel terrace occurs on both sides of the Leen but is greatly obscured by buildings.

ECONOMIC GEOLOGY.

Mr. Wedd. Building stones in the Matlock area are obtained from the Millstone Grits, principally the Chatsworth, Rivelin, or Third Grit on Farley, Matlock, and Tansley Moors.

Road metal around Matlock is got from the Carboniferous limestone. It is principally the limestone above the highest toadstone that is worked, both the blue cherty limestone and the white stone without chert. The beds are easily accessible in the Derwent and Ashover Valleys, where most of the quarrying is done. The limestone is also used for asphalt paving.

[r.Sherlock. The larger pebbles from the Bunter Pebble Beds, picked off the fields in Sherwood Forest, are broken and used for road metal. The gravels capping the hills contain, in the same area, many small pits for the supply of road metal. The late-glacial flood-gravel south of the Trent is used for the same purpose and for gravelling garden walks. The Trent gravel has been extensively used for ballast by the railway companies.

The Bunter Lower Mottled Sandstone is excavated for moulding sand to a considerable extent.

The Keuper Marl is largely worked for the manufacture of bricks in the Nottingham district. The "Marl" is composed of red clay, more or less sandy, alternating with thin greenish sandy beds. No attempt is made to separate the clay and sand and the whole is ground up together. A moderate amount of sand is an advantage, as it prevents contraction in burning. The brickyards are mainly for local use only; for, although the product is of good quality, the expenses of cartage and railway carriage are heavy.

r. Wright. The massive gypsum deposit at the top of the Keuper was originally extensively worked in the neighbourhood of Elton and Orston. Very little local gypsum is now raised.

The limestones at the base of the Lias are quarried on a large scale at the well-known Barnstone Works for the making of hydraulic cement, for which their composition is remarkably adapted.

The Lias clays at Bottesford are dug for the manufacture of bricks. The sand and gravel of the Devon River near this village is cleaner than that usually deposited by the rivers of the district, and has been employed in the neighbourhood for building purposes.

r.Sherlock. The city of Nottingham gets its water supply by borings and wells sunk in the surrounding Bunter formation.

Mr. Wright.

The water supply of the Bingham district is derived almost entirely from wells and a few springs. On the Keuper Marl area the wells sunk into gypsum beds yield the most abundant supply, but the water, although purer and better in many respects than that derived from other sources, is very hard and almost useless for washing purposes.

In the villages which cluster along the brow of the Lias escarpment small supplies of water are obtained from the White Lias by sinking wells to the top of the Rhætic Shales. Springs issue on the face of the escarpment along the upper boundary of these shales, the Spa at Orston being about the best known example.

2. Oxford Area.

Mr. Woodward.

In this area work was carried on under the superintendence of Mr. H. B. Woodward.

The ground to the north and west of Oxford, including Islip, Bladon, Wilcote, North and South Leigh, and Standlake, was surveyed by Mr. T. I. Pocock. Strata from the Inferior Oolite to the Kimeridge Clay and Lower Greensand, with overlying plateau and valley drifts were mapped.

To the east of Oxford, near Wheatley, a small area of Oxford Clay, Corallian rocks, and Kimeridge Clay, with valley drifts, was mapped by Mr. Woodward; while the Lower Cretaceous outliers, with underlying Purbeck and part of the Portland beds, were examined by Mr. G. W. Lamplugh in connection with the Memoir on the Lower Cretaceous rocks. He mapped the Brill outlier, and completed the survey of Shotover Hill.

JURASSIC.

Mr. Pocock.

The *Inferior Oolite*, represented by the Clypeus grit and Chipping Norton limestone, appears in the Evenlode Valley, near Stonesfield, and in a tributary valley extending southwards to Holly Court Farm. The beds are well exposed close to the river, half a mile south of Stonesfield, and they extend somewhat further down the valley than was shown on the old map.

The *Great Oolite Series*, which spreads continuously from Witney to Kidlington and reappears as an inlier at Islip, consists of the usual sub-divisions:—

1. Cornbrash, 9 feet.
2. Forest Marble, 13–35 feet.
3. Great Oolite: white limestone with marl.
4. Great Oolite: flaggy beds with Stonesfield slate.

The lower division of the Great Oolite dips below the surface in the Evenlode Valley not far from Combe Village, and is not again seen in the area, but the upper division (white limestone, etc.) extends along the banks as far as Hanborough. Where its junction with the Forest Marble is visible, there is an intensely hard bed a few inches thick containing fragments of white limestone and

r. Pocock. forming the base of the false-bedded limestones above. In the western part of the district the Forest Marble consists of false-bedded limestones below and pale blue clay above. The false-bedded limestones, which are upwards of twenty feet in thickness at Witney, can be traced along the outcrop as far as Hanborough quarry, where they are about five feet thick. After this they die out rapidly and the subdivision is represented by some thirteen feet of clay with thin stone-bands at the north-western end of Hanborough railway-cutting. The fragmental bed at the base can be followed for some distance along the cutting till it descends below the level of the rails. A short way further oolitic limestones again appear under the clay. These stone-beds strongly resemble the white limestone of the Great Oolite, though in reality they are at a higher horizon. They are seen again at the quarry half a mile north-east of Hanborough. The clay at the top of the Forest Marble is twelve feet thick near Witney, but diminishes eastwards, there being only four feet at Hanborough quarry. Further east the subdivision consists of more rapid alternations of stone and clay.

The Cornbrash apparently does not exceed nine feet in thickness in this region, and probably it is often much less. Wherever there are sections, the Cornbrash is present, but in the neighbourhood of North Leigh, it was difficult to find any trace of the rock between the Oxford and the Forest Marble clays. The outcrop of Cornbrash is somewhat narrower than is shown on the published map owing to the former inclusion with it of the clays at the top of the Forest Marble.*

The mapping of the Corallian escarpment west of Oxford, which was left unfinished by the late Mr. J. H. Blake, has now been completed. The thickness of the two divisions recognised in this region, viz., the Lower Calcareous Grit and the Coral Rag, diminishes from over 100 feet on Wytham Hill to about thirty feet near Sandford, where the outcrop crosses the Isis. It appears, therefore, as if the rock-beds died out in a south-easterly as well as a north-easterly direction, in the Oxford district.

JURASSIC AND CRETACEOUS

The Outliers of Lower Cretaceous "Ironsands" of Muswell Hill, Brill, and Shotover.

'. Lamugh. In mapping the outliers of Lower Cretaceous Ironsand which cap the high ground of Muswell Hill, Brill, and Shotover Hill, a careful search was made for evidence to show whether these deposits were entirely of fresh-water origin, or were partly marine as appeared to be indicated by certain marine fossils preserved in ironstone which have occasionally been found on Shotover Hill. The result of this investigation leaves little doubt that the above-mentioned outliers of "Ironsand," together with the larger sheet

* See H. B. Woodward, "Jurassic Rocks of Britain," vol. iv. 1894, p. 450.

around Coombe Wood immediately south of Wheatley, have been deposited in fresh-water, and that they probably represent the lower portion of the Wealden series of Kent and Sussex. Mr. Lamplugh.

At Muswell Hill the ironsands attain their greatest altitude, the base of the series on the northern side of the outlier reaching the 600-foot contour line; while on the southern side of the Brill outlier the level of this base falls to the 500-foot contour. This southward dip is not, however, persistent at the same rate, as, in the tract south of Wheatley, seven miles farther to south-south-westward, the base sinks only slightly below the 400-foot contour.

The only fossils which have been found in these deposits occur in the form of casts in concretionary ironstone. The segregation of the ferruginous matter appears to have gone on slowly during a very long period; and in most cases any fossils which may have been embedded in the sediments had disappeared before induration took place. But in a few places, generally near the base of the sands, the process commenced earlier, probably by the segregation of lime, which was afterwards replaced by iron; and moulds of organic structures are then preserved in the stone. By experience one learns to distinguish by slight differences the ironstone in which it is hopeless to search for fossils from that in which the casts may occasionally be present.

Near the base of the sands at the south-eastern end of the Muswell Hill outlier numerous blocks of ironstone were found containing casts of *Unio* and *Cyrena*.

At Brill such indications of organisms as were found were less distinct and quite indeterminable, but there can be no doubt that these beds are a continuation of the Muswell Hill series. There are numerous small sections along the outcrop on Brill Common, and although the beds are much confused by slipping, it is possible, by combining the sections, to make out the sequence. Beneath the interstratified sands and silty clays which form the base of the Ironsand series, some of the sections reveal traces of thinly-bedded variable Purbeck Beds, consisting of bright green clay, grey or whitish clay, tough black mud with fragmentary fresh-water shells, and a thin lenticular band of creamy-coloured limestone containing fish-scales, a small oyster and some other shells; the whole series apparently not being more than 3 or 4 feet in thickness. The presence of Purbeck in these sections was recognised long ago by the Rev. P. B. Brodie,* and by Prof. J. Phillips.† Its occurrence has an important bearing upon the correlation of the overlying Ironsands, and strongly supports the suggestion of Phillips that the Ironsands are of Wealden age. These deposits probably belong to the earliest part of the Lower Cretaceous period, while the marine Lower Cretaceous sands of neighbouring districts appear to belong to the latest stage of the same period. Thus, in this part of England a break of considerable

* *Quart. Journ. Geol. Soc.*, vol. xxiii. (1867), p. 197.

† "Geology of Oxford and the valley of the Thames" (1871), p. 418.

Mr. Lamplugh.

stratigraphical importance may occur in the middle of the Lower Cretaceous system.

In mapping the outlier of Shotover Hill, casts of fresh-water fossils were found in ironstone concretions in several places. They were obtained most abundantly and in the best state for identification from a small pit at the west end of the hill, where very fine white sand and silt are dug and sent out of the district, probably for use as a scouring powder. The casts occur in large irregular masses of ironstone lying at or below the base of the white sands, and represent shells belonging to the genera *Unio*, *Cyrena*, and *Paludina*. Similar casts were found at about the same horizon in lumps of ironstone lying at the surface in the field 350 yards north of Westhill Farm, and in the debris of the old ochre pits on the east side of the Horsepath Allotment Gardens.

On the north-western slope of Shotover Hill, above the brickyards in which the Kimeridge Clay is worked, some fragments of ironstone were found that contained casts of marine fossils, including *Trigonia*, *Perna*, and other forms, such as are known to occur in the Portland Stone. Further investigation showed that the Portlandian beds underlying the Ironsands have been affected in places by ferruginous infiltration from the overlying series, and that by this means the Portland Sands have been locally stained so that it is sometimes difficult to distinguish them from the Ironsands, while portions of the Portland Stone, where present, have been sometimes silicified and sometimes partly converted in ironstone through the replacement of lime by iron. The ironstone with marine fossils is best seen in a small sand-pit close to the waterworks reservoir at the western foot of the Shotover ridge; but the most instructive specimens, showing partial conversion of the Portland Stone, were obtained, as above mentioned, from the slope south of the brickyards. The difficulty with regard to the occurrence of marine fossils in ironstone on Shotover Hill is thus explained, and there is no longer any reason for supposing that any part of Lower Cretaceous Ironsands of Shotover are of other than fresh-water origin. The same remarks apply to the neighbouring outlier south of Wheatley; and since we may safely correlate these fresh-water deposits with the beds of the same character at Brill where, as already shown, there is good evidence for their Wealden age, the Shotover and Wheatley Ironsands must also be regarded as marking an early stage of the Lower Cretaceous period.

Gault.

Mr. Pocock.

During the last few years the extensive excavation of Kimeridge Clay at Chawley brickyard near Cumnor has brought to light the existence of a bed of clay above the Ironsand. From this clay Prof. Sollas and Miss Healey obtained specimens of *Ammonites* [*Hoplites*] *interruptus*,* while fragments of the same species were

* *Proc. Geol. Assoc.* vol. xix. 1905, p. 57.

found *in situ* during the course of the Survey. There is, therefore, no doubt that the clay belongs to the Gault. Mr. Pocock.

PLEISTOCENE.

The old deposits of the Isis and its tributaries have now been mapped over the district West of Oxford. The gravels form three well marked terraces. The youngest is raised slightly above the modern flood-level in places, but often it is completely overlapped or cut out by the alluvial clay. The villages of Standlake, Northmoor, Lower Wolvercot, Wytham, and South Hincksey are built upon this gravel. The next terrace, which is the most extensive of the three, is raised upon a bank of Oxford Clay above the level of the lower terrace or the alluvium. The higher parts of the city of Oxford as well as the villages of Yarnton, Cassington, Eynsham, and Stanton Harcourt are all built upon this terrace, which extends as much as three miles from the modern river. The platform on which the gravel rests is 10 feet above the river at its outer margin. The surface varies from 20 feet to 45 feet above the modern flood-level.

The highest of the river gravels occur only in isolated positions near the tops of the lower elevations bordering the Isis valley on the north. They are most strongly marked where the valleys of the Windrush, Evenlode, and Cherwell open into the Isis valley. On the side towards the main river the height of the different outliers is nearly the same (290), *i.e.*, they do not descend as they are traced down stream. On the other hand they rise in level as they are followed into the Windrush and Evenlode valleys. They should perhaps be regarded as delta gravels of the tributaries rather than as deposits of the main river. The height above the modern flood-levels is between 70 and 100 feet. Gravels corresponding to those just mentioned pass up the Cross valley south of Stonesfield, connecting the Evenlode with the Windrush, indicating that the latter river or a branch of it flowed through the gap at the epoch of the high terrace.

Between the high level and middle gravels is another terrace, consisting largely of finely laminated brickearth, but containing at the base a thin pebble-bed which has yielded mammalian remains and the flint implements described by Mr. A. M. Bell.* This terrace has as yet been recognised only at Upper Wolvercote between the Isis and the Cherwell about 40 feet above the flood-plains.

At higher levels than the gravels just described are deposits which were formerly known as "diluvium," and "Northern Drift," consisting of quartzite and quartz pebbles, flints, and a few sandstones in a clay matrix.

* *Quart. Journ. Geol. Soc.*, vol. lx., 1904, p. 120.

Mr. Pocock. Although this "diluvium" is unlike the glacial deposits of other districts, and has not yielded striated stones, the numerous erratics contained in it and its want of stratification suggest that it is a local variety of Glacial Drift. It covers all the outstanding eminences west of Oxford, even the top of Boar's Hill, 350 feet above the river, and extends down the slopes for some distance, but is never found at the bottoms of the valleys nor apparently lower than the high-level gravel. Perhaps deposits of different age and character have been included under "diluvium." That part of it which is seen west of Hanborough appears to be somewhat older than the high-level terrace, *i.e.*, it was formed before the last 80 feet of the main valleys had been excavated, which appears to be approximately the age of the Boulder Clay near London.

3. Southern District—Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher
Mr. George Barrow
Mr. J. B. Hill
Mr. D. A. MacAlister } Geologists.

Mr. Reid. The field-work of 1904 included the completion of the survey of Scilly (Sheets 357 and 360) by Mr. Barrow, who also commenced work on the metamorphic aureole north of Bodmin (336). Mr. Ussher continued the mapping westward from St. Austell (347), till he connected the eastern area with the district already mapped by Messrs. Reid and Scrivenor in the Newquay sheet (346). Mr. Reid in the Mevagissey sheet (353) proved the continuity of the rocks along the line of strike from the sea to the areas already finished by Mr. Scrivenor around Ladock (346), and by Mr. Hill near Probus (352).

It was found to be impossible in the time available completely to settle the correlation in the obscure ground around Gorran Haven, but as far as the work is complete the results are given below.

The rocks of the St. Austell and Black Head area seem to be continuous with the rocks around Newquay, and to be of Lower Devonian age. But south of this belt come rocks the age of which is still in doubt. It will be remembered that in former Summaries mention was made of the sandy strata of Perranporth and of their increasing coarseness towards their northern border as they are traced eastward to Ladock. This conglomeratic character becomes still more marked towards Grampound and Pentewan, recognisable pebbles of the Ordovician quartzite of Gorran, and of still more ancient sheared rocks, being found as the outcrop of these old rocks is approached. Towards Pentewan, the strike of these coarse grits is nearly east and west, and it is noteworthy that this strike if prolonged will cut the strike of the coarse basement conglomerate of Porthluney and Perhaver a few miles out

to sea. It seems evident, therefore, that the conglomeratic beds of Pentewan must abut against much older rocks at no great distance from that place.

On the south side of the coarse grit or conglomerate of Pentewan, Ladock, and Perranporth, occurs a monotonous expanse of sandy strata, which thus far have proved to be entirely devoid of fossils. These sandy strata have now been connected still more definitely with the Portscatho series. The southern limit of the Portscatho strata in the Gorran Haven area, where not a fault line, is a marked unconformity, a coarse conglomeratic basement-bed, largely formed of quartzite pebbles, resting directly on Ordovician strata. This conglomerate strikes about south-west and north-east, and, as above mentioned, if it could be traced a few miles further should run into the Pentewan grit, which runs east and west.

Mr. Ussher.

The relations of these grits and conglomerates to each other and to the surrounding strata are still somewhat uncertain. Mr. Ussher, who has mapped the area north of Pentewan, considers that the sandy beds further south belong to sandy strata of Lower Devonian age, passing beneath the fossiliferous rocks of Black Head. He does not think that there is any direct connection between the basement conglomerate of Porthluney and the Pentewan conglomerate.

Mr. Reid.

During the survey of the Gorran Haven area Mr. Reid was impressed by the convergence of the two conglomerates along their line of strike, and by their increasing resemblance as they approached. It seemed as though the two bands were one and the same, and that they formed the northern and south-eastern borders of a shallow syncline, which might widen westward and include most of West Cornwall.

The absence near Gorran of the Lower Old Red (Dartmouth Slates), so thick and so marked in character only as far away as Watergate Bay, seems also clearly explained if, as suggested in the last Summary, the sandy strata above the Meadfoot series are repeated on the south side of the anticline towards Perranporth and Grampound. These deposits become coarser and coarser as the ridge of old rocks is approached, and towards Gorran Haven an overlap has cut out all the Lower Old Red, and also the lower part of the marine Lower Devonian, so that shore-conglomerates belonging probably to the upper part of the Lower Devonian rest directly on Ordovician or still older rocks. It seems, therefore, that at Gorran we may have the long sought for actual limit of the enclosed sea of the Lower Old Red period.

These questions of correlation are still under discussion, but other discoveries in the Gorran district have an important bearing on them. In the spring of 1904 a visit of Mr. Upfield Green resulted in the discovery of Upper Silurian fossils at Porthluney in masses of limestone in a "conglomerate." * Afterwards the

* *Geol. Mag.* 1904, pp. 289, 403.

Mr. Reid. mapping by Mr. Reid of the surrounding area proved a most complicated structure in the cliffs. The limestone "conglomerate" should be described as a "crush-breccia"; but there is also a true basal conglomerate resting on the Ordovician rocks. This true conglomerate, however, has thus far yielded no recognisable fragments of anything but Ordovician or more ancient strata. It is folded into the underlying Ordovician rocks in a series of sharp anticlines and synclines. After this folding, or connected with it, an enormous overthrust appears to have taken place, driving the sharply folded Ordovician strata over the much newer sandy and conglomeratic deposits. Large masses of crush-breccia have been formed along this plane of overthrust, and the crush-breccia includes a considerable amount of material belonging to various calcareous Silurian rocks not seen at the surface in Cornwall.

The fault-rock or crush-conglomerate just described crops out on the foreshore at Perhaver. It is largely composed of highly fossiliferous Silurian limestone of various characters. One type of rock is a crystalline dolomitic limestone (like Ludlow), full of crinoid-ossicles, but containing nothing else; another is a dull earthy limestone with *Phragmoceras* (determined by Mr. G. C. Crick); a third (extremely abundant at one spot) is a calcareous shale full of corals, the cavities of which show crystals of dolomite mixed with tetrahedrite. At another spot, nearer to Gorran Haven, a group of blocks of the Devonian basal conglomerate seems to have been caught up and dragged along beneath the moving mass of Ordovician strata; but these blocks are only seen at low tide, and their relations to the surrounding confused strata are hidden by beach-sand.

Near Porthluney this great overthrust divides into more than one branch, and seems to send off spurs. The two main branches both yield numerous blocks of limestone, the one yielding the blocks discovered by Messrs. Upfield Green, and Sherborn, the other, discovered by the Survey, yielding a slightly different set, including a limestone full of small brachiopods, referred by Dr. Matley with doubt to *Leptæna scissa* (a Caradoc and Llandovery species).

The determination of the fossils, which are not in a good state of preservation, has given much trouble. Mr. E. T. Newton, after careful study, and a reference of the doubtful brachiopods to Dr. Matley, and the doubtful cephalopods to Mr. Crick, suggests that among these blocks may be representatives of various missing strata, which help to fill the gap between the Ordovician quartzite and the lowest Devonian. The same conclusion is suggested by the very different lithological character of the various blocks, which in a general way suggest Silurian strata; but it is noticeable that the crush-breccia seems to contain nothing resembling Old Red Sandstone, nor does it contain recognisable fragments of rocks older than the Ordovician quartzite. None of the fragments show trace of a cleavage older than that which affects the Devonian strata, and it is noticeable that many of the fossils are neither

crushed nor distorted—their bad preservation is largely due to chemical action, such as the alteration of the rock into dolomite. Mr. Reid.

The bearing of this discovery on the correlation of the rocks of West Cornwall is obvious. We have here various calcareous fossiliferous rocks of ordinary Silurian types; but rocks resembling these are quite unknown among the Cornish strata sometimes referred to the Silurian period. It seems to me, therefore, more probable that the rocks of West Cornwall should be correlated with the Lower and Middle Devonian strata which in lithological character they so greatly resemble.

The Ordovician strata of Gorran Haven fall naturally into two series—a thick mass of fine-grained talcose schist, confined to the Dodman, and the well-known alternations of black slate, fossiliferous quartzite, radiolarian chert, and volcanic rocks. The talcose schist perhaps lies below the quartzite series, though as it is unfossiliferous, and unlike anything else in Cornwall, its age is still uncertain. The quartzite series is probably of Bala age; though its fossils are so peculiar and obscure as to render the exact date somewhat uncertain. After a comparison of those collected in the course of the Survey with those determined by Davidson, and now in the Penzance Museum, Mr. Newton can only draw up the following list:—

Orthis porcata ? *McCoy.*
——— budleighensis, *Dav.*
——— vespertilio ? *Sow.*
——— calligramma, *Dalm.*
Calymene (perhaps C. senaria, *Conrad*).
Trinucleus ?

The shell which Dr. Matley suggests is a fine-ribbed variety of *Orthis porcata* is the same form as the specimen in the Penzance Museum, figured by Davidson as *Strophomena grandis*, the discovery of better-preserved specimens having thrown doubt on its reference to *Strophomena*.

Three days spent in the Upper Devonian districts of Saltash and Devonport (Sheet 348) revealed the fact that the andesitic basalts of that area betray pillow structure. The existence of a bomb-bed at the base of the Wearde grauwacke was also demonstrated. It is therefore probable that Mr. Ussher's original opinion, that these grauwackes may be the result of abnormal conditions locally attendant on the volcanic episode in Upper Devonian times, may be correct, and that their correlation with the Culm Grits must be abandoned. This alteration will be made on the map. Mr. Ussh and Dr Fl

The small area mapped in the region north of St. Austell has produced little of interest. The granite of Luxulian, though sometimes disintegrated, is seldom kaolinized, forming for the most part a rather coarse more or less massive hard porphyritic rock, with irregularly developed floors or pseudo-bedding joints. The distribution of these and of the vertical joints often causes the granite to weather into huge pillow-like and dome-shaped masses, whilst it often splits into massive, more or less even, beds Mr. Ussh

Usher. suitable for building purposes, as at Carbene. Luxulianite—the rock of which the Duke of Wellington's sarcophagus was made—has not been found in place. The original mass occurred on the summit of a hill in a field about 150 yards south of Tregoning Farm (south of Luxulian). The masses into which it was broken may be seen in the hedges.

Barrow. A commencement has been made by Mr. Barrow in the survey of the area north of Bodmin (Sheet 336), where an interesting series of igneous and sedimentary rocks enters the aureole of metamorphism and is then cut off by the granite. In the part examined most of the slate consisted originally of a very fine micaceous and often markedly chloritic mud; nearer to Bodmin the deposit is somewhat coarser. The order of succession in these strata is difficult to make out; but the occurrence on the bank of the De Lank River of a duplicated outcrop of greenstone, associated with peculiar bands of sediment in reverse order at either outcrop, suggests that we have here a sill, intruded along a bedding plane, and folded either into a sharp syncline or anticline. No characteristic fossils have yet been discovered in this neighbourhood, to aid in the determination of the exact age of the accompanying sediments.

Into these already folded and cleaved rocks the great mass of granite of Bodmin Moor has been intruded, its outer margin at this point being slightly oblique to the strike of the folding. In consequence of this obliquity the various bands already mentioned must be at a considerable distance from the granite at one point and in contact with it at another, and it thus becomes possible to trace the gradually increasing metamorphism in bands of very different original composition. This subject will be dealt with more fully later on, when a larger area has been surveyed.

The granite is a typical two-mica Cornish granite, rich in white orthoclase, which imparts a pale grey aspect to the whole; schorl is not a common constituent. The rock varies greatly in its state of preservation; projecting bosses and masses occur here and there exceptionally fresh and hard, when they yield a specially good building stone. Where the granite possesses this aspect it is singularly free from schorl, not only as a component of the rock itself, but also in the form of veins of quartz-schorl. Much of the granite is rather brown in colour and somewhat decomposed, and wells show that this decomposition extends to some depth. Still, the brown granite is essentially the product of normal decomposition, and all the original component minerals, even the biotite, can easily be recognised; but quartz-schorl veins do not occur in anything like the quantity met with in the china-clay modification of the granite.

This china-clay may be described briefly as a tough, coherent, snow-white clay, with a soapy feeling; in it are embedded the quartz and white mica of the original granite. This snow-white china-clay obviously must result from causes very different from those of normal decomposition, and the examination of a china-clay pit

in the initial stages of opening-up soon gives a clue to its origin. Mr. Barr
Were the clay, quartz, and mica to be removed, there would be left in the quarry a vast ramifying network of quartz-schorl or "peach." The peach occurs in veins or lodes from one to two feet thick, having a distinct hade, and a slightly curving course on the whole trending roughly east and west. From these veins proceed minor branches, and from the minor branches proceed mere films, at times no thicker than a sheet of brown paper. If these veins and threads of quartz-schorl rock could be seen end-on, *i.e.*, looking along the trend of the main veins, they would present an appearance not unlike that of a group of leafless trees in winter. These trunks and ramifying branches seem to represent ducts and channels along which travelled the hot gases which changed the felspar into kaolin. A brief examination of the spoil-heap from a china-clay pit suffices to show the enormous quantity of blue quartz-schorl rock that occurs in the clay in this district.

Along the margin of the granite a curious phenomenon was met with; many large blocks of this rock, some weighing more than ten tons, have travelled several hundred yards from the margin of the intrusion. In some cases the marginal slope is low and the method of their transportation is difficult to understand. It seems probable that they slid over snow-slopes; but so far no satisfactory evidence of glacial action has been met with.

The survey of the Isles of Scilly was completed by Mr. Barrow, Messrs. and Mr. Reid and he took the opportunity to examine more closely Barrow a Reid. the peculiar Drift deposits mentioned in the last Summary (p. 30). Close to the highest point in St. Martin's (160 feet above the sea) there still exist traces of a river-gravel almost identical in character and composition with the Eocene river-gravels of Devon and Dorset. The material is mainly subangular or little worn, and consists to a large extent of Greensand-chert, Chalk-flint, hard sandstone probably of Devonian age, and altered slate and greenstone, all derived from the mainland. The stones are not striated or fascetted. They form a thin skin of gravel, probably reconstructed; so that this small patch of gravelly wash can scarcely be mapped as Eocene in place, though it yields fair evidence of the former existence of Eocene deposits not many yards from the spot. Here, therefore, as well as near Penzance, we seem now to have evidence of Eocene rivers flowing westward out into the Atlantic. From these gravels were derived most of the far-transported sub-angular detritus which occurs in greater or less abundance in nearly every raised beach of West Cornwall.

Material from the high-level gravel seems to have been shed during the Glacial Period on to an "ice-foot" or shelf of ice like that which fringes the coast during the winter in high latitudes. When this ice broke up in the spring it was drifted to and fro round the coast, driven into bays, and sometimes during storms it packed so that its inner edge was forced a considerable distance inland and up hill, where the slope was gentle. Where the slope is steep the erratics only occur a few feet above the present sea-level.

ssrs. rrow and id.

Thus appears to have been formed the deposit in the small bay west of St. Martin's Head, where a flat, not exceeding 20 feet above the storm beach, and extending about 100 yards inland, is covered with ferruginous stony loam, crowded with small erratics, many of them beautifully fascetted and striated. A similar deposit in a bay at the north-east end of Tresco lies mainly on the lowland; but also climbs a gentle slope to a height of 100 feet above mean tide, close to which level a striated stone was picked up. Above this height only a few small stones occur, and these might either be shed from a destroyed outlier above, or perhaps driven up by the wind in balls of dry seaweed, as often happens on sloping sand-dunes on these stormy coasts. The different patches of glacial gravel vary somewhat in composition; but they are all characterised by abundance of rocks which cannot be found in Scilly except in gravel, though all resemble known rocks from the mainland of Cornwall and Devon.

The new evidence throws a flood of light on the climatic conditions which prevailed during the Glacial Period. Scilly stands well out in the Atlantic, full in the present track of the Gulf Stream, and the erratics only occur near the sea-level, except where they have obviously been driven up gentle slopes. It seems impossible therefore to explain the accumulation of ice by any local change of land or sea, or by water less salt; we are compelled to assume that the surface water of the Atlantic in these latitudes was then so cold that Scilly could be fringed with ice during the winter. To find such conditions we must now travel many degrees further north.

MINING.

Mac- ster.

The work of collecting information from the scattered mine-plans, and the transfer of the lodes to a uniform scale on the 25 inch and 6 inch maps is now nearly as complete as we can make it. But a considerable number of plans of abandoned mines have disappeared and cannot now be traced; and in other cases no plans seem ever to have been made. The 25 inch mining maps will shortly be deposited in the library for reference by the public. The more important lodes have also been reduced on to the 1 inch maps, several of which will be engraved in the course of 1905.

Hill.

Mr. Hill has been engaged throughout the season on a memoir on the Camborne and Redruth mining district, which will soon be finished.

QUARRIES.

Barrow.

The area surveyed during the year happens not to include many stone-quarries of importance, except the large De Lank granite-quarry, near Bodmin. The rock here worked is appreciably finer in grain than the main mass of the Cornish granites, and this seems to render it harder and specially durable. It possesses the typical pale-grey colour; moreover the small size of the white felspars

Mr. Barro

imparts to it an appearance, when used on a large scale, that seems more attractive than that of the coarser rock. One of its most striking features is the almost total absence of patches of colour different from that of the body of the rock, and in this respect the De Lank granite stands almost unrivalled. The Eddystone, the Bishop's Rock and the Beachy Head Lighthouses have been built of it, as well the stone-work of the Tower Bridge over the Thames. It has also been used for the Docks of Hull and Bombay, as well as in a great number of well-known public buildings.

One of the most noticeable features of Bodmin is the curious mottled look of the fronts of the houses. They have a peculiar chequered aspect, due to the mingling of pale yellowish blocks with others of a reddish-brown colour. This is due to the mode of occurrence in the quarry of the stone of which the town is built. The soft killas has a persistent low-dipping cleavage, but is also traversed by a number of nearly vertical joints running parallel to one another. Along these cracks reddish-brown iron-oxide has been deposited. When the stone is quarried, these brown-stained clean-cut faces are made use of to save the labour of dressing ; and when all the natural-faced material has been used up, the rest of the stone, which has a pale yellow colour, is trimmed with the chisel, or cut with a small axe. This latter mode of treatment is rendered possible by the extremely soft nature of the highly-micaceous rock, which, however, is a singularly stable material where not exposed to the splitting action of the frost. Quarries, both large and small, in this type of killas abound in the Bodmin area, as it is the chief building stone both in the town and in the field walls.

4. South Wales District—Carmarthenshire and Pembrokeshire.

Mr. Aubrey Strahan, M.A., F.R.S., District Geologist.

Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A.
Mr. O. T. Jones, B.A., B.Sc.
} Geologists.

Mr. Straha

The field-work of 1904 lay in the Ordovician tract between Carmarthen and Whitland, and in the Old Red Sandstone and Carboniferous area between Pendine and Narberth. Little progress was made in the surveying of the Pembrokeshire Coalfield in consequence of the services of Mr. Strahan and Mr. Jones having been devoted for a great part of the year to the work of the Royal Commission on Coal Supplies.

rahan. The sub-divisions adopted for the rocks above the Llandilo group correspond almost precisely to those established by Marr and Roberts in 1885.* One of the results of the past year's work has been to show that a large part of a tract supposed by Misses Crosfield and Skeat to be occupied by *Didymograptus bifidus* beds is formed of *Tetragraptus* beds, brought up along the axis of an anticline, with the usual accompaniment of numerous strike-faults and overthrusts. Speaking generally, we may describe the structure of the district as that of a series of anticlines whose axes trend a little south of west, and which have been pushed from the north and overfolded towards the south. These are further complicated by innumerable minor folds and by constant overthrusting and strike-faulting. North and south faults are rare.

Cleavage sets in along a line running westwards from Carmarthen about three miles north of St. Clears. Northwards from that line it increases rapidly in intensity; south of it it is imperceptible.

The series of igneous rocks of Coomb includes andesites, rhyolites, and intrusive diabases. There is reason to believe them to be of the age of the *Tetragraptus*-shales.

The mapping of the Old Red Sandstone has rendered apparent the increasing unconformity between it and all the older rocks. A marked conglomerate at its base often lies with a gentle inclination upon steeply upturned Ordovician rocks. The earth-movements thus evidenced were followed by others of the same character and direction, at a later date, as proved by the fact that they affect both Old Red and Ordovician rocks equally.

So far as regards the north side of the Pembrokeshire Coalfield, the whole series, from the green strata in the lower part to the grey and brown sandstones and marls in the upper part, appears to belong to the Lower Old Red Sandstone, but in the grand cliff-sections of South Pembrokeshire some quartzitic sandstones and breccias, with red marls and greenish shales, intervene between the Lower Old Red Sandstone and the Carboniferous base, and may prove to be of Upper Old Red Sandstone age. *Pteraspis* has been obtained from the Lower, and *Modiola* and *Lingula* from the supposed Upper Old Red Sandstone of Skrinkle Haven.

In the investigation of the Carboniferous Limestone Series and of the faults affecting it, the zonal work of Dr. A. Vaughan has proved of great utility. By the identification of certain faunal horizons, partly during a visit paid by him for the purpose, it has been possible to prove that the "main limestone" as exhibited in the north crop corresponds to a part only of the "main limestone" of the south coast. The lower half of the latter disappears

* *Quart. Journ. Geol. Soc.*, vol. xli., p. 476.

northwards, in that direction in which the whole series rapidly attenuates, both in Monmouthshire * and throughout South Wales. A conglomerate in the limestone at Pendine, mentioned in the *Summary of Progress* for 1902, p. 43, appears to have been formed during a temporary upheaval of a limited area, in the period of the *Syringothyris*-zone. Mr. Strah

The examination of the Coal Measures and Millstone Grit, so far as it has gone, points to the probability that many massive rocks, hitherto regarded as Coal Measures, will have to be classed as Millstone Grit. Some fossiliferous bands near Tenby, detected more than 50 years ago by the Rev. O. Fisher, but never described, yield a fauna which may throw some light on this question. The lowest seam of coal that has been worked lies about 260 feet above what we take to be the Farewell Rock.

Though no Trias has been found in Pembrokeshire in a form that can be shown upon the map, evidence of its former presence has been obtained in the contents of interstices between the blocks of some remarkable breccias. The breccias appear to have been formed before the deposition of the Keuper Marl, and some of the open crevices in them to have been filled subsequently with that material. The breccias are traversed by north and south faults which are thus proved to be of post-Triassic age.

The faults and folds affecting the area surveyed in 1904 belong to two systems which, though approaching one another westwards, still remain distinct. The one affects the region north of tne coalfield and runs a little south of west. It presents repeated proofs of over-thrusting and over-folding towards the south. The other, which is a continuation of the Gower system, runs a little north of west and presents repeated proofs of over-thrusting towards the north. Between the two there is a tract, one or two miles in breadth, of undisturbed ground. Cleavage is associated with both systems and increases in intensity to the north and south respectively on both sides of the undisturbed tract.

Some low ground extending westwards from Carmarthen is occupied by boulder-clay and gravel which indicate a line of drainage of glacial age, probably running from east to west. On parts of the Old Red outcrop there are many boulders of igneous rocks, of which the source has not yet been identified. South Pembrokeshire has so far proved to be free from glacial deposits.

CAMBRIAN AND ORDOVICIAN.

The work of the past season has been continued in the neighbourhood of Carmarthen, St. Clears, and Whitland, on the Cambrian, Ordovician, Silurian, and Old Red Sandstone rocks. Messrs. Cantrill & Thomas.

* The Country around Abergavenny, *Memoir Geol. Survey*, 1900, p. 19.

ssrs. ıtrill and ɔmas.

The rocks below the Old Red Sandstone include the following subdivisions, in descending order :—

SILURIAN (part of) (Upper Silurian of Murchison)	Llandovery.	*Lower Llandovery (?).*—Grey quartzitic sandstones, and shales and mudstones, with a conglomerate at the base; the whole weathering olive-green; fossils rare.
ORDOVICIAN (Lower Silurian of Murchison)	Bala	*Slade and Redhill Beds.*—Blue-grey mudstones, with bands of decalcified sandy limestone and some micaceous sandstones; crinoids, corals and brachiopods locally abundant. *Sholeshook and Robeston Wathen Limestones.*—Dark thin-bedded limestones, generally sandy; with crinoids, corals, brachiopods, and the trilobites *Cybele verrucosa, Encrinurus sexcostatus, Illænus Bowmanni*, etc. *Dicranograptus Shales.*—Black and brown-weathering shales, with *Dicranograptus, Diplograptus, Climacograptus* and *Leptograptus.*
	Llandilo	*Didymograptus Murchisoni Beds* :— *b.* Flags and dark impure limestones, with *Ogygia Buchi, Asaphus tyrannus, Trinucleus*, and other Llandilo forms. *a.* Black and yellow-weathering shales with abundant *Didymograptus Murchisoni*,* passing upwards and downwards locally into ashes.
	Arenig	*Didymograptus bifidus Beds.*—Blue-black soft shales, with *D. bifidus* and other forms characteristic of Dr. Hicks's Lower Llanvirn fauna. *Ogygia marginata* or *Tetragraptus Beds.*—Blue-black iridescent-weathering shales and blue mudstones with *Didymograptus hirundo, D. extensus, D. nitidus, Tetragraptus, Ogygia marginata, O. Selwyni, Obolella plumbea.* Conglomeratic grits are strongly developed towards the base.
CAMBRIAN.	Tremadoc	*Peltura punctata Beds.*—Blue mudstones with interbedded thin grits; *Peltura punctata* and *Ogygia marginata.*

Tremadoc.

Thomas. *Peltura punctata Beds.*—South of Carmarthen, as was described in the *Summary of Progress* for 1903, page 32, these beds are well-

* Including *D. Murchisoni* var. *geminus.*

exposed in the valleys of the Ffrwd and Glasdwr. In an old road east of Aber-cyfor Farm they yield abundant *Peltura punctata*, with an occasional *Ogygia marginata*, but in Nant-Cwm-Ffrwd *Peltura* is less abundant, while the *Ogygia* is more common. Thence they run to Moelfre on the left bank of the Towy, and crossing the river appear immediately below the Old Red Sandstone conglomerate at Green Castle. At Cwrt-hîr they were described by the Misses Crosfield and Skeat.* To the west of Cwrt-hîr, owing to the closing-in of the anticline of which these rocks form the core, they take a turn to the south and strike south-westwards towards Glog-ddu, passing partly below the Old Red Sandstone, and being partly cut out by a fault to the north, with the result that they disappear at Fernhill. Mr. Thomas

Some mudstones cropping out at Pwntan contain *Ogygia marginata*, *Peltura punctata*, and a few lamellibranchs, and are evidently of Tremadoc age.

Arenig.

Ogygia marginata Beds.—Between the Tremadoc shales and mudstones containing *Peltura* and the higher beds with *Ogygia marginata* without *Peltura* is intercalated a series of grits and conglomerates.† These hard rocks form a dome-like anticline giving rise to the Allt Cystanog and Bolahaul ridges. The anticline pitches east and west at its two ends respectively, and along its southern side, in the high ground to the north of the Pibwr valley, is for the most part inverted, so as to have an apparent dip northwards at about 80°. This hard core is wrapped round by mudstones of Arenig age containing *Ogygia marginata*, *O. Selwyni*, *Orthis alata*, *O. caligramma*, *Bellerophon perturbatus*, etc., which are well exposed at Pensarn, and near the New Lead Shaft at the eastern end of the anticline, and in a small quarry 200 yards north-west of Cilwaunydd Farm.

The blue *Ogygia marginata* Beds, in Glan-Pibwr lane, yield *Ogygia marginata* in abundance, associated with *Phyllograptus* (cf. *angustifolius*).

In a stream to the south of the main road from Carmarthen to Swansea, and south-west of Ty-gwyn, the passage of these mudstones up into the *Didymograptus bifidus* shales is shown.

Crossing the river Towy, to the south of Ystrad the blue mudstones take on the form of graptolite shales; at various places to the south of the Ystrad ridge they have yielded *Ogygia marginata* together with the extensiform graptolites *Didymograptus hirundo* and *D. extensus*. These forms are characteristic of the Upper *Tetragraptus* Shales, and the fact that they are associated with the

* *Quart. Journ. Geol. Soc.*, vol. lii., p. 525 (1896).

† Through lack of palæontological evidence these rocks were provisionally classed as Bala by the Misses Crosfield and Skeat. Their true age has been made clear by subsequent study of a greater number of species, and by the structure of the district.

Mr. Thomas. characteristic fossils of the *Ogygia marginata* Beds proves that these two groups are equivalent and pass laterally the one into the other.

Messrs. Cantrill and Thomas. The strata to which the name *Tetragraptus* Beds has been applied occupy a belt of generally low ground, traversed by the Great Western Railway, and extending westwards from Llanllwch through Banc-y-felin and St. Clears towards Whitland. They form the core of an anticline with an approximately east and west axis, bounded on both the north and south by *Didymograptus bifidus* Beds. The southern limb of this anticline, which may be referred to as the Llanllwch-Llangynin Anticline, is inverted to the extent of 20° to 30°, that is, the beds have a reversed dip northwards of 60° to 70°.

Blue-black shales and mudstones with local developments of coarse ashy sandstones and conglomerates, form the bulk of this series. The shales frequently show a superficial chocolate or purple staining, and are often marked by iridescent characters which serve broadly to distinguish them from the overlying *D. bifidus* shales. Their upper limit has been taken at the top of certain soft blue-black mudstones in which extensiform species of *Didymograptus* abound, but in which no *Didymograptus bifidus* has been found.

Mr. Thomas. Fossils occur sparingly in thin bands at Castell-y-gaer, Waun-corngam, Cwm Crymlyn, near College, and in the railway-cutting Mr. Cantrill. close to Banc-y-felin; further west they are well seen and have yielded fossils at Llwyn-crwn, Pont-y-Fenni, and Nant-yr-allwyn between St. Clears and Whitland.

Mr. Thomas. To the south of this main area of *Tetragraptus* Beds and separated from it by a mass of faulted and inverted *Didymograptus bifidus* shales, lies another mass of *Tetragraptus* Beds extending from Hafod-wen, south of Carmarthen, south-westward through Llangynog to Lambstone Farm. On the north this mass is faulted against the *D. bifidus* shales of the Ystrad and Waun-corngam ridges, and on the south against the Tremadoc Rocks of Pwntan and Cwrt-hîr. The anticlinal structure of the Bolahaul district makes itself again evident in the neighbourhood of Fernhill and Llangynog, where it brings up the ashy grits and conglomerates.*

Messrs. Cantrill and Thomas. *Didymograptus bifidus Beds.*—These shales form two belts running a little south of west, one on either side of the main mass of *Tetragraptus* Beds already described. On the south of that mass they stretch from Ystrad to the River Cywyn and westwards through St. Clears towards Whitland, and are inverted. On the north they run from Trevaughan Hill, Carmarthen, with many displacements, through Merthyr, to the south of Mydrim, and thence towards Llanboidy.

They consist of soft, blue-black shales, occasionally stained a bright red. Good sections occur in Cwm Crymlyn, along the Ystrad and Waun-corngam ridge, in Cwm-du-hên to the north of Merthyr, at Blue Boar (St. Clears), at Woolstone and Castle Hills near Llandowror, and again at Forest near Whitland.

* The conglomerate at Glog-ddu referred to in the *Summary of Progress* for 1903, p. 35, as possibly forming part of the Old Red Sandstone series has now proved to belong to the *Tetragraptus* Beds.

Llandilo.

Didymograptus Murchisoni Beds.—(*a*) The lower and greater part of this subdivision consists of blue-black shales characterised by the occurrence of *D. Murchisoni* var. *geminus*; they are, however, indistinguishable lithologically from the underlying *D. bifidus* Beds. Near their base, on the southern outcrop, there is a well-marked horizon of sandstones and grits about 300 feet thick, which appears to be represented near Llandowror and again along the northern outcrop by at least one well-defined belt of ashes. The grit-beds are quarried along the ridges stretching from Ystrad to Llangynog, while the ashes at Llandowror and those on the north outcrop, which range from Nant-y-ci (Merthyr) through Bron-y-gaer to beyond the Fox Inn at Llangynin, are also worked. Messrs. Cantrill and Thomas.

On the north side of the anticline the shales are exposed and yield typical fossils south of Merthyr, in a quarry at Plas-parcau south of Mydrim, at Pen-lan north of Llangynin, and, on the south side, at Pentre-newydd near Llandilo-Abercowin.

The shales with *D. Murchisoni* extend almost continuously from the north of Carmarthen through Melin-Ricket, Cefn-crŵth, Pant-yr-hendre, Castell-gorfod, and thence towards Llanboidy. In their lower part they are represented by black and yellow-weathering shales, crowded with *Didymograptus Murchisoni*, which upwards become ashy, and finally pass into thicker-bedded ashes about 80 feet thick. The ashes are succeeded by flagstones (*b*) probably not more than 60 feet thick which have yielded *Ogygia Buchi* and other typical Llandilo Flag forms. All these subdivisions are well-exposed in one quarry at Pant-yr-hendre, near Mydrim.* The flags are very fossiliferous in Pen-y-bigwrn Quarry.

On the south of the anticline a limestone containing characteristic Llandilo Limestone forms has been quarried at Lower Court and Pant-dwfn near St. Clears, and at Clog-y-frân near Whitland. In no case, however, is it possible to ascertain its relationship to the rest of the sequence, for at Lower Court the nearest exposure shows *Didymograptus bifidus* Beds, and whether any *D. Murchisoni* shales are associated with the limestone there is no opportunity of discovering; and the same is the case at Pant-dwfn. At Clog-y-frân, where *Didymograptus bifidus* Beds, Llandilo Limestone, Bala Limestone, and Redhill Beds may all be examined in the farmyard, the Llandilo Limestone is faulted on all sides, so that here again its relationship to the *D. Murchisoni* Beds remains in doubt. Mr. Cantri

* Roberts, *Quart. Journ. Geol. Soc.*, vol. xlix., p. 166. (1893).

Lower Bala.

ssrs. ntrill and omas. *Dicranograptus Shales.*—Returning to the north side of the anticline we find the lower *Dicranograptus* Shales succeeding the Llandilo Flags. They consist of brown-weathering flaggy black shales with abundant fossils. They are well exposed on the St. Clears Road south of Mydrim village, in a quarry belonging to Lan Farm to the west of Pen-y-bigwrn, and in many other places to the immediate north of the outcrop of the *D. Murchisoni* beds. In their lower part occur abundant specimens of *Trinucleus*, *Dicranograptus*, and *Diplograptus*, while *Leptograptus* is common in the higher part. Upwards they pass into calcareous shales and limestone, well developed under Mydrim Church; and at the cross-roads at Mydrim post-office these calcareous beds have yielded *Leptograptus* and *Diplograptus*. These are succeeded immediately by typical black upper *Dicranograptus* Shales with abundant *Diplograptus*, *Climacograptus*, and, less frequently, *Dicranograptus*.

r. Thomas.

r. Cantrill. On the south side of the anticline, although the passage from Llandilo Limestone to the *Dicranograptus* Shales is nowhere exposed, it seems that black shales rest directly upon the Llandilo Limestone, either through the absence of or a change of character in the brown-weathering shales. The black shales towards their summit weather buff and yellow, and are well exposed in the village of Llandowror.

Bala Limestone Series.

Roberton Wathen and *Sholeshook Limestone.*—These limestones on the south of the anticline immediately succeed the *Dicranograptus* Shales. It is noticeable that in their lower part they differ locally in their lithological characters; occasionally, as at Foxhole near St. Clears, and at Cwm-cae-du near Llandowror, the lowest band is a hard dark-grey limestone of considerable purity, such as at the last-named locality is seen close to the shales; elsewhere, as on the road between Llandowror and Pentre-Hywel, there is a gradual passage of the black *Dicranograptus* Shales up through sandy brown beds into a limestone which is very sandy. The purer limestone may represent the Roberton Wathen Limestone, while the other may represent that of Sholeshook.

The latter runs from a quarry at Craig-y-Deilo near Llandowror, as a well-marked scarp in a north-westerly direction, crosses the Tâf, and comes up again in the yard at Clog-y-frân Farm, where it is inverted, so as apparently to overlie the Redhill Beds. The same limestone is faulted up in several narrow inliers south-west of Llandowror.

Upper Bala.

Redhill and Slade Beds.—These blue-grey mudstones form the eastern slope of Pale Mountain west of Llandowror. The Redhill Beds pass upwards into similar mudstones, distinguished only by

being interbedded with thin decalcified sandy limestones, in which corals, crinoids, and brachiopods abound. These constitute the Slade Beds of Messrs. Marr and Roberts*; they are exposed at Cnyciau, west of Llandowror. Mr. Cantri

On the north side of the anticline the newest strata met with in the district surveyed are certain blue-grey irregularly-bedded barren mudstones, which succeed the black *Dicranograptus* Beds without break, though with no apparent equivalent of the Bala limestones. In view of their character and position; they may be the equivalents of the Redhill and Slade Beds described above. Mr. Thoma

SILURIAN.

Lower Llandovery (?).—A thin band of pebbly quartzitic grit or conglomerate some 10 feet thick overlies the Slade Beds and forms the scarp at the top of the eastern slopes of Pale Mountain. It is succeeded by alternating grits, shales, and mudstones, exposed both on the mountain and also in quarries in the valley of the Tâf south of Forest Tunnel. Fossils have been found only in a small section in Great Pale Wood; they include forms which will probably indicate a Lower Llandovery horizon. Mr. Cantri

IGNEOUS ROCKS.

The examination of the igneous rocks at Coomb, Llangynog, referred to in the *Summary of Progress* for 1903 (p. 35), has now been completed. The rocks consist of the following:— Mr. Cantr

4. Intrusive Diabase.
3. Andesitic lavas and ashes.
2. Felsitic lavas and ashes.
1. Andesitic lavas and ashes.

The lavas and ashes have a general dip towards the north, and the order given above represents the descending order. They are all well-exposed in a deep dingle at Coomb, but the crops do not match on its two sides, so that it seems necessary to assume the presence of a fault along the course of the stream.

The full succession is best seen on the eastern side of the valley; on the west, the lofty hill crowned by the ramparts of Castell Cogan is made up of felsites; the upper andesites come in farther north, between Gelli and Tre-hyrn. The intrusive diabase is well exposed on the west side of the dingle at Tre-hyrn.

Typical specimens of the several rock-types are thus described by Mr. Thomas:—

The Andesites and Associated Tuffs.

The flows are usually compact dark grey to green rocks studded with fine vesicles which appear as dark spots and reach a maximum of one-fifth of an inch in diameter. Mr. Thom

* *Quart. Journ. Geol. Soc.*, vol. xli., p. 476 (1885).

Mr. Thomas. Under the microscope the rock is seen to consist of a mass of lath-shaped oligoclase and andesine felspars set in a ground-mass which consists essentially of felspar microliths. These microliths are arranged in bunches and fan-like aggregates, frequently giving rise to a variolitic structure. The larger felspars are exceedingly fresh and are twinned according to the albite law.

No ferro-magnesian mineral is now to be seen, but what appears to have been augite is represented by pseudomorphs in chlorite and secondary quartz.

The vesicles are filled with radiating fibres of chlorite and lined with a thin layer of secondary quartz.

The rocks originally were vesicular augite andesites, but some slides indicate that hornblende andesites were also represented.

The tuffs, which make up a large portion of the series, are of an olive-green colour and are mostly banded; they consist chiefly of finely-divided volcanic material which is largely felspathic. The banding is due to variations in texture and not to difference of composition. More coarsely fragmental rocks also occur in which the fragments consist chiefly of pieces of andesitic pumice with the vesicles filled with chlorite, and vesicular andesite with well-developed flow structure, set in a mass of broken felspars and microliths. In the upper series of andesitic tuffs occasional fragments of the underlying rhyolites are met with.

Felsites.

These rocks are of a pale grey to blue colour in the field weathering white and cream. Under the microscope they appear to be devitrified rhyolites and show well-formed phenocrysts of orthoclase and oligoclase felspars. Occasionally a well-marked flow-structure is apparent, and sometimes the ground-mass is perlitic. Secondary silicification of the rock is observed in most cases, while there are many instances of beautiful spherulitic structure.

A secondary crystallization of felspar has taken place in some cases.

Diabase.

The diabase of Tre-hyrn is a fairly fine-grained dark grey rock in which the constituent minerals are inconspicuous in the hand specimens. Under the microscope it is seen to vary from a fairly coarsely ophitic diabase to a granular type. The felspars are oligoclase-andesine varieties usually much decomposed, giving rise to epidote. The augite in large plates or granules is of a pale green colour usually much altered to chlorite and calcite, while chlorite occurs in irregular patches throughout the rock. Ilmenite skeletons passing into leucoxene are most conspicuous in all cases.

The rock at Pentre-newydd seems of a different type; it has probably been a diabase, but is much altered. The augite seems to have been converted into hornblende which is now completely

decomposed. There is a considerable development of calcite in the rock due in all probability to the decomposition of the ferro-magnesian mineral. Mr. Thon

A small mass of felsitic lavas which occurs at Capel Bethesda near Glog, Llangain, exhibits a general north-north-east strike; the mass is faulted off from the *Tetragraptus* Beds which lie to the north and south. In hand-specimens the rock is pale blue-grey in colour, and contains crystals of pyrites.

A larger mass of porphyrite occupies the top of the hill to the north of Lambstone Farm, Llangynog; on the west it is faulted against *Didymograptus bifidus* Beds, and on the east is associated with some of the lower members of the *Tetragraptus* Beds.

A small mass of diabase of an intrusive character occurs to the west of Capel Bethesda, and has been quarried at the cross-roads to the north of Pen-gelli-uchaf. It is in a very rotten condition, much calcite having been developed.

The felsitic rock at Capel Bethesda, near Glog, is seen to consist of phenocrysts of orthoclase and oligoclase in a microcrystalline and spherulitic ground-mass. The rock is identical in character with many of the Coomb rhyolites.

The rock at Lambstone, Llangynog, is of a blue-grey colour, felspar crystals being conspicuous. Under the microscope it is seen to consist of phenocrysts of oligoclase repeatedly twinned and orthoclase set in a fine-grained ground mass of a felsitic character. Small idiomorphic pseudomorphs in chlorite also occur, probably after hornblende. From the character of the rock it is suggested that the mass may prove to be intrusive.

With regard to the age of the igneous rocks of Coomb it is not possible to speak with complete certainty, as the complex is faulted off from all the surrounding ground, with the exception of the Old Red Sandstone which oversteps all the other rocks along the east side of the valley. Messrs. Cantrill & Thomas.

The rocks faulted against the complex are *D. bifidus* Beds, and olive-weathering micaceous shales with grits which have yielded a few horny brachiopods and trilobites, and which probably are *Tetragraptus* or *Ogygia marginata* Beds. As the igneous mass has almost certainly been upheaved, and as no such igneous rocks have been met with in the *D. bifidus* or higher beds, it follows that they are of *Tetragraptus* age or older. Nothing more definite than this can be determined at Coomb.

The igneous exposures west of Glog agree closely in lithological character with those of Coomb, and are also intimately associated with *Tetragraptus* Beds.

OLD RED SANDSTONE.

Thomas Cantrill. The basal green beds, with one or more thin bands of conglomerate, extend from Green Castle on the western side of the Towy towards Glog-ddu near Llangain, where they are locally faulted out, the higher division of red marls being brought into contact with conglomerates of Arenig age. From this neighbourhood they persist westwards as far as the mapping has proceeded. Upwards they pass into the red marls and sandstones of Lower Old Red Sandstone age which extend southwards to the coast.

. Jones. The outcrop of the Old Red Sandstone south-east of Narberth is less than two miles in width from north to south. It is intersected by deep valleys which furnish good sections, especially in the lower strata. The lowest beds consist of about 500 feet of green marls with subordinate flaggy micaceous sandstones, which are sometimes coarse and pebbly.

The junction of this green marl subdivision with various members of the older rocks beneath, as exposed in several places, is invariably associated with a few feet of somewhat ferruginous conglomerate. The marls near the base are frequently dark in colour and sometimes so closely simulate the older rocks above which they lie as to suggest that they were derived from their washings.

Succeeding the green marls and graduating down into them is a mass of red marls with race of the type usual in the Old Red Sandstone elsewhere. They are, however, interrupted at frequent intervals by thin bands of grey, green, or brown sandstones, by green marls, or even by massive conglomerates. This last feature is clearly shown in a cutting on the Pembroke and Tenby Railway near Gloyn, south-east of Narberth, where a conglomerate associated with coarse pebbly sandstones attains a thickness of over 30 feet. The probable presence of strike faults in the lower part makes it difficult to ascertain the total thickness of the marls, but it must be at least 1,200 to 1,300 feet.

Between the top of these red marls and the base of the Carboniferous rocks there intervenes a thickness of about 600 to 700 feet of strata, about equally divided between green, grey, and brown sandstones of varying degrees of coarseness, and green, red, and brown marls. This part of the series is also noticeably more micaceous than the lower part. The dip near the base is about 80° to 90°, but it steadily diminishes towards the south.

'. Dixon. Near Llandyfaelog and along the North Crop to the coast at Tan-y-lan the Senni Beds retain their general character of green, micaceous flags, though to the south-west of Pont-Antwn the thickness of strata to which this description applies is greater than to the east, the change being due to both the lower part of the Brownstones above, and the upper part of the underlying red marls passing laterally into green, micaceous flags, indistinguishable from

those of the Senni Beds. A similar lithological change affects much more of the red marls than the extreme top, for near Ferryside green flags form a considerable proportion of this subdivision, though they are rare to the north of Llandyfaelog. Mr. Dixon

The Brownstones show considerable variations in character along their outcrop. Thus near Felindref some red and greenish sandstones at their top are thickening westwards so rapidly that one mile further on they form the greater part of the group. Below them, north of Llech-dwnny, there are red marls to a considerable thickness, but at Gledwyn these marls become very thin and the Brownstones appear to be represented mainly by red and green sandstones in which marls are subordinate.

In the Gwendraeth-fàch near Kidwelly the Lower Limestone Shales, with sandstones and a line of pebbles at their base, rest directly upon Senni Beds, the whole of the Brownstones after a course of many miles along the North Crop having apparently been overstepped. Whatever be the age of the Brownstones there is no doubt that the Senni Beds belong to the Lower Old Red Sandstone. This section therefore confirms the conclusion previously arrived at* that the Carboniferous hereabouts rests unconformably on the Old Red Sandstone, although in exposures the bedding of the two formations appears to be perfectly parallel.

Tenby.—The lowest beds hitherto examined in the Tenby district are red marls, of Lower Old Red Sandstone age, as evidenced by the frequent occurrence in them of fragments of *Pteraspis* along the cliffs of Old Castle Head. Here beds extending down about 2,400 feet from the top of the subdivision are exposed. Besides red marls they include red and green flags and sandstones, cornstones, and beds of race, and occasionally thin quartzitic sandstones, though none of sufficient thickness to be mapped except on the coast where they are useful in determining the throw of faults. A group of conglomerates also occurs at the top of the red marls at Skrinkle Haven and to the west, as well as along the Ridgeway which is almost entirely composed of it. Though it has not yielded *Pteraspis*, it is stratigraphically inseparable from the beds below. It is distinguished from those above by the absence of thick quartzites and by the rounded character of the included fragments. Moreover, though 140 feet thick at Skrinkle, it is absent on Caldy Island, only 3½ miles away, though the quartzite group above it shows no diminution. This lateral disappearance of conglomerates may be due to wedge-bedding, but as will be seen, other evidence points to overstep by the quartzites above.

The uppermost part of the Old Red Sandstone throughout the district south of the Pembrokeshire Coalfield as far west as the longitude of Manorbier is characterised by quartzitic sandstones

* Summary of Progress for 1903, p. 38 (*Mem. Geol. Surv.*).

[r. Dixon. and breccias made of subangular fragments, purple-hearted but weathering grey. These rocks are well exposed on Caldy Island and at Skrinkle Haven, and at both places they are sharply separated from the beds below, but with no sign of an unconformity, for fragments in their base are similar to those in the breccias above, while the bedding above and below the junction is quite parallel. Higher up in the group are interbedded red marls and sandstones and occasional pale greenish-grey soapy shales, in one of which near the overlying Carboniferous series several fossils were found, including *Modiola* and *Lingula*. The highest bed which may be referred without doubt to the Old Red Sandstone is green, hard, sandy shale. This passes up through a few inches of more sandy material with small quartz-pebbles into a dark-grey laminated shale which undoubtedly belongs to the Lower Limestone Shales.

Although the change takes place so rapidly that specimens showing both Old Red Sandstone and Lower Limestone Shale may be easily obtained, it seems to be a passage rather than a sharp break. With respect to the age of the quartzites, such fossils as they have yielded tend to link them with the Carboniferous series. Stratigraphically, also, they seem to pass up into that formation but are sharply separable from the mass of red strata below. Moreover, their occurrence is constant, whereas the conglomerates below them are impersistent. For these reasons we think it probable that this quartzite-group is of Upper Old Red Sandstone age though there is no visible unconformity between it and the Lower subdivision with *Pteraspis* as there is in other districts between the Upper and Lower Old Red Sandstone. But the apparent parallelism between the two formations by no means proves conformity, for at Kidwelly (p. 41) where there is no doubt about the existence of an unconformity, it is equally difficult to detect any want of parallelism.

CARBONIFEROUS.

Carboniferous Limestone Series.

Much additional light has been thrown on the correlation of the subdivisions of the limestone with those of other areas by Dr. A. Vaughan. He has found that the Carboniferous Limestone series of the Bristol district contains several faunas in definite succession, which he has been able to recognise in some other districts. Our hearty thanks are due to him for much information respecting the zones present at Bristol,* and for identifying the corresponding beds at Kidwelly and Tenby, both on the spot during a short visit in 1904 and by means of specimens sent him for examination. The following notes on the limestone of both places, and also some of the observations on the faulting, embody the chief results which

* Published subsequently in *Quart. Journ. Geol. Soc.*, vol. lxi., p. 181

have been obtained up to the present by the application of his zoning to the South Wales limestone. The following Table gives a list of the fossils selected by him to characterise his zones, but for details, reference must be made to the paper mentioned. Mr. Dixon.

Main Limestone		ε
	Dibunophyllum.	
	Seminula.	
		δ
	Syringothyris.	
		γ
	Zaphrentis.	
		β
Lower Limestone Shales	Cleistopora.	
		α
	Modiola.	

α, β, γ, δ, ε represent intermediate horizons.

As far as general results are concerned it may be said that wherever the Carboniferous Limestone in South Wales was examined last year, the faunal sequence proved to be the same as at Bristol, though as the range of some forms varies from place to place, somewhat different assemblages are occasionally met with. Again, the sequence wherever it is complete commences or ends with the same fauna in the two areas, and where, as will be seen, at Pendine and Kidwelly some of the intermediate faunas are absent, other explanations are forthcoming. Some local details will now be given.

Kidwelly and Pendine.—Lower Limestone Shales with the fossils characteristic of the *Cleistopora*-zone are exposed near Rogerlay, and also at Old Forge where they immediately overlie the Lower Old Red Sandstone, but they have yielded no evidence of the presence of the lowest zone, that of *Modiola*, which in South Wales and Bristol has been found only where there is a passage up from the Old Red Sandstone. Near Kidwelly no evidence was found of zones of the Main Limestone below the *Seminula*-zone. This gap in the sequence may be due to beds being cut out by the strike-faults of the Kidwelly disturbance,* but is more probably accounted for by actual unconformity in the Carboniferous Limestone itself, as will presently be seen. The upper zones of the Main Limestone on the contrary are well represented by the limestone of Mynydd-y-gareg and Fan, the dark and light, partly oolitic, limestones † belonging respectively to the *Seminula*- and *Dibunophyllum*-zones. The

* Summary of Progress for 1903 (*Mem. Geol. Surv.*) p. 170.

† *Op cit.*, p. 40.

Mr. Dixon. higher subzone of the latter (characterised by *Lonsdaleia floriformis*) is very well-developed and fossiliferous, and is succeeded by the Upper Limestone Shales which here represent horizon ε, and immediately underlie the basal quartzite of the Millstone Grit.

At Fan the base of the massive limestones which constitute the 'Main Limestone' is proved by its fossils to belong to the *Seminula*-zone. As this is not far above the Old Red Sandstone it appears that here, as at Kidwelly, the lower zones of the Main Limestone, amounting at Tenby to one-half of the whole, are either absent or exceedingly attenuated.

Messrs. Dixon and Jones. Evidence bearing on this question has been obtained on the coast at Pendine where a conglomerate in the limestone had already been observed by Mr. Strahan.* The section was re-examined with the object of identifying and measuring the zones. It was found that the *Cleistopora*-zone and the lower part of the *Zaphrentis*-zone were determinable and were followed by current-bedded detrital limestone with occasional lines of fossils, generally broken and unrecognisable, but apparently belonging to no higher horizon than the upper parts of the *Zaphrentis*-zone. This is overlain by the conglomerate mentioned above. In two pebbles from the conglomerate fossils were found, the species of which point to their having been derived from a horizon probably not higher than a low part of the *Zaphrentis*-zone. The limestone that succeeds the conglomerate belongs undoubtedly to the *Seminula*-zone, and it is followed by the *Dibunophyllum*-zone, both having the same lithological and palæontological development as at Kidwelly. Consequently the *Syringothyris*-zone and possibly a small part of the *Zaphrentis*-zone, though they are present close by to the south-west at Tenby, as well as in the Bristol area, are absent in this intervening locality. The conglomerate, consisting as it does of more or less rolled fragments of limestone derived from different bands, points to the locality having been within reach of wave-action at the close, at least, of the period of those zones, and it is be to noted that this local movement nearly, if not quite, corresponds in time with the volcanic outbursts evidenced at Weston-super-Mare.†

The total thickness of the limestone above the conglomerate is rather more than 600 feet, that is, about the same as that of the corresponding zones near Kidwelly, which it will be remembered there constitute the whole of the 'Main Limestone.' Also the highest beds are referable to the same horizon, ε, as at Kidwelly. Hence it appears that at Pendine we have a mass of limestone which palæontologically and lithologically corresponds closely with the 'Main Limestone' of the western end of the North Crop, but which corresponds to the upper half only of the limestone of Tenby. Further the base of this limestone is a conglomerate resting with some unconformity on the limestone below.

Mr. Dixon.

* Summary of Progress for 1902 (*Mem. Geol. Surv.*), p. 43.

† *Quart. Journ. Geol. Soc.*, vol. lx., p. 147.

It is probable, therefore, that the absence, complete or almost complete, of beds between the Lower Limestone Shales and the *Seminula*-zone at Kidwelly and Fan is due to a still greater unconformity at the same horizon. Mr. Dixon

Tenby.—The whole of the Carboniferous Limestone Series, except the extreme top, may be examined in the cliffs between Skrinkle and Lydstep Havens. The fossils show that all the zones, subzones and horizons of the Carboniferous Limestone series of Bristol are exposed with the following exceptions:—the lower subzone of the *Seminula*-zone, and the upper subzone and horizon ϵ of the *Dibunophyllum*-zone. Dealing now with these exceptions and some lithological characters of the zones we find that the Bryozoan Limestone of the Avon Gorge, horizon *a*, is probably represented, though not in exactly the same form, at Skrinkle. The *Modiola*- and *Cleistopora*-zones are represented by the Lower Limestone Shales as at Bristol. Upwards, the shales of the *Cleistopora*-zone are interbedded with limestones with chert-nodules, which in turn give place to massive limestones also with chert. At the base of the massive beds, as at Bristol, a band yields *Zaphrentis Phillipsi* and *Spiriferina octoplicata*, an association which characterises horizon β. Above this no shales interrupt the succession of limestones until the top of the *Seminula*-zone is reached, and in higher parts of the series, so far as it is exposed, a few thin bands only occur. Cherts recur in one band in the upper part of the *Seminula*-zone.

The lower subzone of the *Seminula*-beds, which at Bristol is characterised by *Productus semireticulatus* and *Caninia* is not distinguishable, the first two forms not extending up into the *Seminula*-beds. There is no break in the sequence—the difference between the two districts is due to the fauna of the *Seminula*-beds not overlapping the preceeding one to the same extent as at Bristol.

The highest limestone exposed south of Lydstep is the lower part of the *Dibunophyllum*-zone, but fossils characteristic of the upper part have been found north of that place. To the south, next to the limestone, but separated from it by a vertical lode of limonite, a group of cherts was proved in working the ore. In some of the cherts Dr. G. J. Hinde, who has been good enough to examine them, has recognised radiolaria, and in others wavellite is frequent in cracks. In these respects they agree with the Bishopton cherts, which occupy a similar stratigraphical position.

Millstone Grit and Coal Measures.

Tenby.—The Upper Carboniferous rocks at Tenby and to the west of it are separated from the limestone throughout the district examined by a great strike-fault, and consequently it is unknown there what beds immediately succeeded the limestone. The Lydstep infold of Upper Carboniferous rocks is possibly also bounded by faults. Both here and at Tenby itself the series consists of shales and fine grey sandstones with little or no coal, which may be Millstone

Mr. Dixon. Grit, but resemble that of Gower, while they are dissimilar to that of Kidwelly and Pendine. The recurrence of marine conditions in this part of the series is evidenced by the presence of *Pterinopecten* and *Goniatites* in shales in First Bay, north of Tenby, as noticed by the Rev. O. Fisher.

Mr. Jones. *Coast-section near Amroth.*—From Telpen Point westwards the coast-section shows the lower beds of the Coal Measures. At a cascade west of the Point a small fault throws up the top of the Farewell Rock, and beyond it the cliff is formed by the strata above that rock. The following descending section commences at New Inn, Amroth, 1000 yards west of the cascade.

	Ft.
Hard, yellowish-grey quartzitic sandstone, forming the top of the cliff for some distance, seen to	30
A vein of carbonaceous shale with thin streaks of coal distributed through it. The structure is peculiar and suggests considerable squeezing. This vein runs in the cliff for a long distance and is said to have been worked by a level in one place near New Inn; about	3
Fireclay, about	2
Black shales with some sandstone and mine, about	20
Hard, thick-bedded sandstone with some shales, about	10
Black shales with much mine, in balls near the top, in thin bands lower down; 75 feet to	80
Gap of about 200 yards, due to a landslip, and representing a thickness of about	80
Coal, worked along the crop in the vicinity, but thickness unknown	
Black shale and fireclay, about	3
Sandstone with thin shale bands	4
Shales with a few thin sandstone beds; 20 feet to	25

The highest sandstone mentioned in this section is seen in the road from Marros to Amroth to be succeeded by a few feet of sandy shales overlain by a thin coal-seam with fireclay. This coal has been worked near and along the crop from Amroth westwards.

TRIAS.

Mr. Dixon. At several places along the coast from Tenby to Skrinkle and also on Caldy Island, the evenly-bedded Carboniferous Limestone is replaced by breccia consisting of angular blocks of limestone of all sizes up to masses weighing hundreds of tons, thrown together without arrangement or any sign of crushing. These are cemented together by crystalline calcite or amorphous stalagmite, the latter being generally red and passing in some cases into soft, red marl indistinguishable from Keuper Marl. Occasionally the stalagmite and calcite do not fill the whole of the spaces between the blocks, and the cavities may or may not be filled up with grey sandstone. Similar sandstone was found in a few places in fissures in the limestone apart from the breccias.

The breccia often extends from bottom to top of cliffs ranging up to more than 100 feet in height and may continue for over 100 yards. In several places it is crossed by clean-cut planes having a north-and-south direction, and accompanied by breccia

which differs from that around it in being finer, more uniform, and much less compactly cemented. In some places where these planes cross the boundaries of masses of breccia, they appear to have displaced them, but whether this be so or not there can be no doubt from the accompanying brecciation, and in some cases slickensiding, that the planes are faults. These belong to the N.N.W. system, extensively developed in South Wales, and consequently the coarse breccia, which is obviously older, is presumably of considerable antiquity. The following explanation best accounts for the observed facts. The red stalagmite and marl point to a Triassic or pre-Triassic age for the aggregation of the fragments, and the sizes of the masses of breccia, and the fact that the walls of undisturbed limestone occasionally overhang, suggest that this remarkable rock originated as debris in great caves in the limestone at a time when it was elevated above the saturation-level. This was probably the condition of the land after the operation of the pre-Triassic movements, which have so powerfully affected this district. Subsequently, in Triassic times, the masses of cave-debris were bared by denudation and at the same time solution was replaced by deposition, the interspaces in them being filled up, generally completely, with calcite, or with stalagmite coloured red by material brought in from the surface, or even with red marl itself where descending water, presumably, had a clearer course from above. This change of conditions suggests that subsidence followed the period of elevation. The surface of much of South Pembrokeshire is the top of a plateau under 200 feet in height, which is probably the same feature as that which, in Gower and in the Bridgend district, passes beneath Triassic rocks, and which was probably, therefore, the surface in Triassic times. The fact that the larger masses of breccia are cut off at the plateau level, strongly supports the conclusion that their age is pre-Triassic, and accounts for the entry of Triassic material. Mr. Dixon.

FAULTS AND DISTURBANCES.

It has been already pointed out that along the north side of the Llanllwch-Llangynin anticline the *Tetragraptus* Beds dip northwards under *D. bifidus* shales, whereas to the south of it there is inversion on a large scale. The anticline, therefore, is overfolded from the north, probably accompanied by much minor folding. On its north side the lower part of the *D. geminus* shales, with their included bands of ashes, is repeatedly cut by faults which run in a general west-south-west direction, almost parallel to the strike, and are generally downthrows south or overthrusts from the north, thus considerably increasing the apparent thickness of the shales and the number of the included ash-beds. To the north of Merthyr a strike-fault cuts out the *Didymograptus Murchisoni* Beds altogether for a short distance, and brings the *Dicranograptus* and *Didymograptus bifidus* Beds into contact. Messrs. Cantrill and Thomas.

Mr. Thomas. South of the anticline the ground is much cut up by strike faults; in the inverted belt of *D. bifidus* and *D. geminus* shales ranging from Ystrad westwards to the River Cywyn there are numerous overthrusts causing frequent repetition of the grit-beds.

Mr. Cantrill. In the neighbourhood of St. Clears strata greatly differing in age are brought into contact by similar strike-faults, as for instance in the case of a wedge of Redhill Beds let down into the middle of *Didymograptus bifidus* Beds at Forest (between St. Clears and Whitland); the Redhill and Slade Beds between *D. bifidus* Beds and Lower Llandovery Beds at Forest Tunnel; and a number of complications in the *Dicranograptus* Shales, Bala Limestone, and Redhill Beds west of Llandowror.

Messrs. Cantrill and Thomas. These disturbances appear to be of at least two ages. That much folding and faulting had been completed prior to the deposition of the Lower Old Red Sandstone is proved by the striking unconformity at the base of that formation, the Old Red Sandstone lying indiscriminately on folded and faulted beds of divers ages; but it is equally certain, from the general high dips at its base and from the fact that some of the older rocks are faulted up into it, that much disturbance was subsequent to the deposition of the Old Red Marl.

Mr. Thomas. Cleavage is well marked on the north side of the Llanllwch-Llangynin anticline; it is constant in direction, but less so in intensity. Many folds with east and west axes were formed prior to the cleavage; but no folding subsequent to the cleavage has yet been noticed in the older rocks.

Mr. Jones. The Red Roses Disturbance mentioned in the *Summary of Progress* for 1903 has been studied this year in its effect on the Carboniferous Limestone outcrop. From Lanteague the base of the limestone shows no sign of disturbance as far west as the Trenewydd Quarries, but close by Lower Limestone Shales make their appearance a quarter of a mile north of that base, so that for a distance of half a mile there are two outcrops of the lower beds of the Carboniferous Limestone. The repetition is due to faulting with a downthrow north, which agrees exactly in direction with the Red Roses Disturbance, but ranges nearly a quarter of a mile south of the last known point on that disturbance. At Gelli-halog, about a mile farther west, the outcrop shows a still more marked displacement northwards, with structures of a slightly different character. Folding, accompanied by faulting, has the general effect of throwing the Carboniferous rocks into a sharp anticline followed northward by a shallow syncline. The axes of these folds run in a direction about W. 15° to 20° S., with a tendency to turn into an east and west course as they are followed westwards. The anticline crosses the Ludchurch Limestone Quarries in a direction east and west. The syncline probably passes a short distance north of the quarries.

If these two repetitions be regarded as forming part of the Red Roses Disturbance, the disturbed belt must have a width of no less than three-quarters of a mile.

Mr. Dixon.

The completion of the mapping of the divisions of the Old Red Sandstone has brought to light the existence of a disturbance which appears to connect the Kidwelly* with the Llandyfaelog† disturbance. It probably leaves the latter where the River Gwendraeth-fâch turns southwards out of the chief fault-line. For a short distance it lies along the course of the river, but continues its southerly course where the river turns west again. It has a westerly downthrow sufficient to cut out the whole of the Senni Beds, north-east of the Llech-dwnny, that is, about 500 feet. The course of the fault bends gradually to south-south-west, but is soon lost in obscure low ground, beyond which, however, a fault with a downthrow in the opposite direction appears so exactly in the same line that it is difficult to suppose that the two are not connected. Though running in part nearly north and south, there is further reason to think this line of fault forms part of the Llandyfaelog and Kidwelly set of disturbances rather than of the north-north-west system of faults. For at Gwempa it is accompanied by an anticline running north-north-west, of which the axial plane is inclined to the east, and which can be traced for a considerable distance to the south parallel to the fault. Again, this anticline appears to be a buckle in the centre of a much larger syncline. Although to this fold the presence of Carboniferous Limestone and of the higher beds of the Old Red Sandstone north of the Llandyfaelog disturbance is probably in part due, both syncline and the accompanying buckle die out at the major disturbance, to which the outcrops to the north are parallel. This association of the fault with folding distinguishes it from the series of simple north-north-west breaks, and the folding is such as to suggest a connection with the Llandyfaelog disturbance.

It has been found also that another fault forming part of the Kidwelly disturbance runs to Fan, where it probably throws *Seminula*-beds, as identified by Dr. Vaughan, against Millstone Grit, though the actual junction is obscured by Drift. Here, as elsewhere along its course, the newer beds are on its south-east side.

There is strong presumptive evidence of the pre-Triassic age of the powerful east and west folding and faulting in the Tenby district in the facts that it preceeded both the formation of the plateau mentioned on page, and the deposition of what is probably Keuper Marl in the interstices of the limestone, and this conclusion is supported by its parallelism with the pre-Triassic folding of other parts of South Wales. In general the faults are overthrusts with downthrows to the north, and the axial planes of the folds are inclined to the south. The rocks at Tenby and to the south, where sufficiently argillaceous, cleave along planes dipping steeply southwards. This structure disappears gradually northwards.

* Summary of Progress for 1903 (*Mem. Geol. Surv.*), p. 170.

† *Ibid* for 1902, p. 45.

Mr. Dixon. In addition to the overthrusts visible in the cliffs the mapping of the zones of the Carboniferous Limestone has led to the detection of others. Along one of these, north of the Ridgeway, the Lower Old Red conglomerates have been thrust over various members of the Carboniferous Limestone series from the highest at Penally to the lowest at Palmerslake. Here the overthrust passes into an overfold which, near Coppybush, inverts the whole series, Old Red Sandstone and Lower Limestone Shales, 50° beyond verticality. What is probably another overthrust runs under Tenby and along the Ritec, throwing limestone belonging to the *Zaphrentis*-zone close to the Upper Carboniferous, pointing to a downthrow to the north of at least 500 yards.

Innumerable north-north-west faults are exposed on the sea-cliffs. That some of them are much later than the pre-triassic movements just mentioned is clear from the fact that they cut through the masses of breccia described on p. 46, which are themselves younger than these movements. There is independent evidence, however, that the north-north-west faults are later than the east and west disturbances, for there are several cases visible on the coast, as, for instance, north of Tenby, of small north-north-west faults cutting through and displacing small east-and-west overthrusts.*

GLACIAL.

Mr. Cantrill. Near St. Clears boulder-clay spreads irregularly over the lower ground or runs over the lower hills. It consists of a blue clay packed with rounded pebbles of Ordovician shale, sandstone and grit. Occasionally the matrix becomes more sandy and forms mounds with a light soil. Much of the ground lying east of St. Clears is occupied by a thin coating of this gravelly drift, and gravel-pits have been opened in mounds at Waun, Plâs-y-gwer, and Trefanty. South and west of St. Clears similar gravel has been dug at Maes-Oland and Mylet, and is exposed at the Rectory, (half a mile east of Llangynin Church), at Parc-glâs, and on the Laugharne Road between Lower St. Clears and Morfa-bâch. North of the low ground followed by the Great Western Railway at St. Clears, the drift rapidly thins away, so that in the deep valleys west of Mydrim there is little or none.

Mr Thomas. The bottom of the valley, through which the Great Western Railway runs from Carmarthen to Banc-y-felin, is covered with boulder-clay and flanked with gravels, which evidently indicate the existence of a glacial drainage-system, probably from east to west, along the Towy and Llanllwch valley. Here also the gravels form mounds or terrace-like accumulations rising to about 100 feet above the valley bottom. To the south of this valley a large area of boulder-clay overspreads the *Tetragraptus* Beds along the line of Fernhill Brook, but to the north the drift is seldom thick and is confined to the more open valleys.

* A similar instance on the Gower Coast was described by Mr. Strahan in the Summary of Progress for 1902, p. 47.

Mr Thomas.

A good example of an overflow valley is seen at Cwm-du-hên to the north of Merthyr. The drainage passed over the east and west ridge on which Merthyr stands by a *col* situated a little north of the church. The lowest point on the *col* corresponds in level to gravels ranged along the 400 feet contour on the south of the ridge. A narrow gorge leading from it northwards deepens to the extent of 200 feet in about one-third of a mile, and yet is almost dry. It was formed presumably by an overflow in a northerly direction, when the main valley was filled with ice up to the 400 feet level.

Another overflow valley of similar type seems to be represented by the gap cut through the *Didymograptus Murchisoni* Beds at Trevaughan, to the north of Carmarthen.

The gravels of the Carmarthen district, judged by the elevation of certain more or less definite terraces, seem to represent stages in the recession of the ice-sheet.

Mr. Jones.

The drift in the Ludchurch area is on the whole of an indefinite type and is distinguished with difficulty from rainwash in some cases or from rock decomposed in place in other cases. In hollows and on the bottom of the smaller valleys on the Old Red Sandstone ground there is generally found bluish or reddish clay. Upon this there usually lie boulders, most of which can be traced to a source at no great distance, but which include also far-travelled blocks, sometimes in fair abundance. For instance, near Newhouse Farm, large numbers of igneous rocks foreign to the district occur along with those of a pebbly grit which crops not far off. Isolated boulders of similar igneous rocks are also scattered about on the higher driftless ground around and east of Newhouse.

In a cutting on the Pembroke and Tenby Railway about two miles south of Narberth Station drift of a more definite kind is exposed. The matrix is a sandy clay with thin seams of sand, and in it are imbedded a few large boulders and a great number of smaller partly rounded fragments, the majority being well striated. Old Red sandstones and marls prodominate; but hard fine-grained grits, olive-green mudstones and black graptolitic shale-fragments (*Dicranograptus* Shales?) are not uncommon. A few boulders and fragments of a white quartzite resembling Millstone Grit occur. Among other miscellaneous material may be noted one small flint and one specimen of flint or chert. Other exposures in the same cutting show gravelly material the pebbles in which appear to have been exclusively derived from the Old Red Sandstone.

Over the Limestone-outcrop the drift is irregularly distributed. It is associated with the peculiar material described in the *Summary of Progress* for 1903, which consists largely of decomposed Millstone Grit. An account of the foreign boulders in the drift is reserved for a future occasion.

Mr. Dixon. No glacial deposits have been found hitherto in the Tenby district. Remains of the Raised Beach described in the *Summary of Progress* for 1899, pp. 154, 155, occur at intervals along the coast between Tenby and Manorbier, and on Caldy Island, but more frequently the platform only on which it rested can be recognised.

POST GLACIAL.

Mr. Thomas. A great mass of peat, about half a square mile in area, has formed on the boulder-clay of the Llanllwch valley, and now acts as a watershed; it drains east into the Towy with a fall of about 57 feet, and west into the Cywyn with a fall of not more than 30 feet.

ECONOMIC GEOLOGY.

Messrs. Cantrill and Thomas. Rough building-stone and road-metal is occasionally obtained from many quarries in the Lower Arenig grits at Llangynog, and on the high ground north-east of Whitland. The felsitic rock of Lambstone Farm, Llangynog, is used for the same purposes. The *Didymograptus geminus* grits are quarried extensively along the Ystrad to Pen-plâs ridge south of Llanllwch, at Ystrad, Waun-corngam, Wern-ddu, Fforest, and Pen-plâs. On the north side of the main anticline *D. geminus* ashes are quarried, chiefly for road-metal, at numerous points between Nant-y-ci (Merthyr) and the Fox of (Llangynin); also at Forest, between St. Clears and Whitland. The *D. Murchisoni* ashes are extensively quarried for the same purpose at Pant-yr-hendre south of Mydrim, and at several other small quarries in the same line of outcrop. The use of all these materials is confined to the district.

Mr. Cantrill. The Llandilo limestone of Lower Court and Pant-dwfn, and the Bala Limestone of Foxhole and Trefanty, Llandowror and Faynor, all near St. Clears, are quarried occasionally for flags, building-stone, and road-metal, but they are unfit for lime-burning. The Llandilo Limestone, however, was formerly extensively burnt at Clog-y-frân, but the kilns are abandoned, lime now being obtained from the Carboniferous Limestone. The Lower Llandovery sandstones have been quarried for building-stone at Forest and in Great Pale Wood, east of Whitland; flags and building-stone are sometimes obtained from the Old Red Sandstone, especially from the green beds at the base.

All the Ordovician shales have been opened up in small quarries for draining purposes. Their black colour has led to attempts to find coal, even in recent years.

The water-supply in the St. Clears district is obtained from springs and shallow draw-wells.

Limestone has been extensively quarried at several places, but only at the Blackrock Quarry near Tenby is much work being done at present. Mr. Dixon.

Ironstone (limonite), in the form of a vertical lode, was once worked for a few years at Lydstep.

II.—PETROGRAPHICAL WORK.

The work of this department during the year 1904 has been carried on principally by Dr. Flett, as in previous years, but he has received an increasing amount of assistance from the younger members of the field staff, who have the necessary amount of time and petrological training. Mr. H. H. Thomas has undertaken the examination of all rocks sent in from the South Wales district, and Mr. E. B. Bailey and Mr. E. M. Anderson have examined and reported on a number of Scottish rocks, while Mr. Harker continues to investigate the igneous rocks of the Inner Hebrides. In future it is intended that certain of the geologists shall make themselves acquainted with the microscopic petrography of the districts in which they are working, and shall devote a part of each winter season to microscopic work under the general charge of the petrographer. Dr. J. S. Flett.

The whole of the collections of sliced rocks and slides have now been transferred to new rooms, and the specimens of British rocks exhibited in the Museum are being cleaned, rearranged, and recatalogued.

In March Dr. Flett was one of a party of Survey officers who visited the Tayvallich area in the West of Argyllshire to examine the pillowy lavas, tuffs, and agglomerates, which had been mapped by Dr. Peach during the previous season. These igneous rocks have their original structures preserved in a remarkably perfect manner, and their field relationships to the Highland black schist, limestone, and "boulder-bed," are revealed in excellent natural sections. In these respects they are unique among the rocks of the Southern Highlands, and a large number of them have been submitted to microscopic examination. A special report on this subject is in course of preparation and will appear shortly.

In connection with the memoir on Central Perthshire (Sheet 55 Scotland) which is now in the press, Dr. Flett has made a detailed investigation of the newer intrusive rocks of that area, including the granites and their basic modifications, and the dykes. A very large variety of these rocks has been found within the boundaries of that sheet, and in this respect it is typical of the Southern Highlands. The plutonic phases comprise various types of granite and diorite, while, among the dykes, aplites, pegmatites, granite porphyries, porphyrites, lamprophyres, basalts, and peridotites

Dr. J. S. Flett.

occur. The lamprophyres are of especial interest on account of the numerous modifications they present.

The revision of the maps of the Scottish coal-fields has involved a re-examination of the Pentland Hills, near Edinburgh. The mapping having been completed by Mr. E. H. Cunningham Craig and Dr. Peach, the petrographer visited the district in October 1904 in order to make himself acquainted with the characters of the rocks in the field. This was followed by a re-examination of the microscopic sections from this area in the collections, together with a large number of additional slides of rocks collected by Mr. Tait. The subject is one of much difficulty because the rocks are in nearly all cases decomposed, but the evidence obtained justifies the conclusion that highly acid rhyolites, trachytes, andesites of various kinds, basalts and olivine dolerites all occur in this area, together with quartz porphyries, lamprophyres, and other intrusive rocks. The other igneous masses of the Edinburgh Sheet (32 Scotland) are also being investigated in preparation for a new edition of the map and memoir.

From the Glencoe district Mr. Clough has forwarded many specimens of granites, dykes, contact altered igneous and sedimentary rocks, andesites and igneous brecias. Mr. Grant Wilson, Mr. Muff, Mr. Bailey, and Mr. Grabham have also sent in many examples of schists, gneisses, granites, lavas, etc., from this quarter. This material, which presents many points of the greatest interest, has as yet been only partly examined. Dr. Peach, Mr. Hinxman and Mr. Anderson, who are engaged in mapping the district north of the Great Glen, have selected for examination types of the supposed inliers of Lewisian gneiss and of the Moine gneisses and schists which surround them. In working up this material the petrographer has received valuable assistance from Mr. E. M. Anderson. Igneous rocks from the Bathgate hills and the Garlton Hills have also been received for description from the field officers engaged in revising the maps of the Scottish coal-fields.

The number of slides cut from South Wales rocks continues to increase, and these have been handed over to Mr. H. H. Thomas, who has undertaken their investigation. The principal additional contributions received from the English staff include a set of rocks from Gorran in Cornwall, sent in by Mr. Clement Reid, rocks from the Scilly Isles (Mr. Barrow) and a series of specimens of proterobases, schalsteins, cherts, etc., from East Cornwall and West Devonshire, collected partly by Mr. Ussher and partly by Dr. Flett during a brief visit to that locality.

III.—CHEMICAL WORK.

Dr. W. [redacted]rd.

During the past year the Chemical Department has been fully occupied.

Complete analyses of five Cornish rocks have been made for Mr. Clement Reid. These have proved very interesting, several of them containing boron and fluorine. Dr. W. Pollard.

Complete analyses were also made of three Scotch rocks for Dr. Flett and Mr. Clough; one of these contains traces of the rare earths.

Some time has also been spent over the preliminary examination of a mineral from Scotland which contains the rare earths in considerable quantity.

Six analyses of limestones and three of coals were made, as well as a series of specific gravity and water capacity determinations.

Details of analyses are appended.

CORNISH ROCKS.

(3660a). Analysis of specimen from Pentire Quarry, Newquay. Rock used for road mending and for agricultural purposes.

SiO_2	50·98
TiO_2	1·25
Al_2O_3	16·13
Cr_2O_3	Trace
V_2O_3	Trace
Fe_2O_3	4·20
FeO	3·24
MnO	·17
NiO	Trace
CaO	5·50
SrO	Trace
BaO	·20
MgO	7·28
K_2O	4·82
Na_2O	2·99
Li_2O	Trace
H_2O 105° C.	·44
H_2O above 105° C.	1·46
FeS_2 (Pyrites)	·43
P_2O_5	·74
Cl	·07
CO_2	·58
	100·48
Less O for Cl	·02
Total	100·46

The "available" potash and phosphate were estimated (Dyer's method), and gave:—K_2O ·054%, P_2O_5 ·053%. Hence the rock cannot well be of any direct manurial value, though by weathering, of course, a fair quantity of potash would become available. It seems more likely that its use is more in the direction of mechanically improving the soil.

A fair dressing would be, say, 3 cwt. superphosphate, containing about 35% $Ca_3(PO_4)_2$ and 1 cwt. potash salts of, say, 50% K_2O. This would mean that to get the same effect with this rock about 50 tons per acre would be needed.

r. W. Allard.

Analyses of 1. Granite of Lamorna Quarry, Cornwall. 2. The decomposed granite washed for Kaolin, from Georgia Works, Cornwall.

	1.	2.
SiO_2	70·17	71·15
TiO_2	·41	·16
Al_2O_3	15·07	19·41
Fe_2O_3	·88	1·32
FeO	1·79	·09
MnO	·12	·09
CaO	1·13	·21
MgO	1·11	·45
K_2O	5·73	1·44
Na_2O	2·69	·05
Li_2O	·11	·03
H_2O 105° C.	·18	·16
H_2O above 105° C.	·70	5·09
P_2O_5	·34	·07
Cl	·06	Trace
F	·15	·11
S	·04	not found
B_2O_3	Strong Trace	·33
	100·68	100·16
Less O for Cl & F	·07	·04
Total	100·61	100·12

Analyses of 1. Brown Hornfels from Lamorna Granite Quarry (enclosure of Killas altered by the Granite). 2. Greisen, with tourmaline and topaz, St. Michael's Mount.

	1.	2.
SiO_2	47·45	69·42
TiO_2	1·26	Trace
Al_2O_3	27·48	15·65
Fe_2O_3	1·44	1·25
FeO	8·60	3·30
MnO	·15	·39
CaO	2·23	·63
MgO	4·14	1·02
K_2O	2·75	4·06
Na_2O	1·62	·27
Li_2O	·09	·81
H_2O 105° C.	·17	·06
H_2O above 105°	1·97	·54
(CoNi)O	·02	
Cr_2O_3	·02	not found
V_2O_3	·03	
P_2O_5	·26	·40
Cl	·04	Trace
F	·37	3·36
B_2O_3	Trace	·59
	100·09	101·75
Less O for F & Cl	·17	1·41
Total	99·92	100·34

Analysis of a Gannister for Mr. Clough. Dr. W. Pollard.

Bed forming a small cascade a few feet under (upstream from) No. 6 Limestone in river North Esk at first bend S.W. of Kirkettle (old) mill, half way between Roslin Castle railway station and Auchindinny railway station.

SiO_2	96·98
TiO_2	·51
ZrO_2	·08
Fe_2O_3	·38
Al_2O_3	1·43
CaO	·18
MgO	·12
K_2O	·20
Na_2O	·03
Li_2O	Trace
H_2O 105° C.	·03
H_2O above 105° C. & trace of organic matter	·44
	100·38

Some of the rock was treated with hydrofluoric acid, and the residue handed to Mr. Thomas for examination, whose account of the minerals identified is given below:—

The residue insol. in hydrofluoric acid contains the following minerals.

Zircon. Abundant in well formed prisms, doubly terminated by pyramids of the usual habit, also in more or less elliptical grains, the long axis corresponding to the long axis of the original crystal.

Tourmaline. Well-shaped crystals, terminated by the simple rhombohedron, of brown, green and blue colours, less abundant than the above but about equal in quantity to the rutile.

Rutile. In long tetragonal prisms, with ill-defined terminations, showing twin lamellæ crossing the prism at 65° to the vertical axis. Also in knee-shaped twins with the same law as the lamellæ. In colour they range from pale yellow to deep amber.

Anatase. In tabular crystals, flattened parallel to the base, of a steel blue colour sometimes almost colourless, occurs in no great quantity.

Iron Ores. Black in colour and irregular in shape, probably ilmenite.

Corundum? A dirty green mineral, with a high refractive index and conchoidal fracture may belong to this species.

Two rocks analysed for Dr. Flett, who describes them as follows:—

9519. This is a basic intrusive igneous rock which is found in association with the limestone, quartzite and boulder bed of Central Perthshire. It has been converted into a scapolite-hornblende-schist which contains also small quantities of epidote or zoisite, biotite, iron-ores and sphene. The scapolite accounts for the presence of the chlorine in such quantities. This type of alteration is not at all common in the basic intrusives of this region and is being investigated more fullyon further collectionsof material. There seems no escape from the conclusion that chlorine has been introduced into the rock, either before or during metamorphism.

11017. An analysis of the Aegerine-Riebeckite-Gneiss of Carn Chuinneag, Ross-shire. It corresponds very closely in composition with riebeckite-granite and paisanite. The high percentage of alkalies and the low percentage

W. Ward. of lime and magnesia are exactly in accordance with the microscopic characters of the rock. (*see* Summary of Progress of the Geological Survey for 1903, pp. 54 and 81. 1904.)

9519.

SiO_2	49·11
TiO_2	1·88
Al_2O_3	13·19
Fe_2O_3	3·18
Cr_2O_3	·02
FeO	8·55
MnO	·42
CaO	11·27
MgO	6·76
K_2O	1·72
Na_2O	1·91
H_2O 105° C.	·11
H_2O above 105° C.	·39
(CoNi)O	·07
V_2O_3	·05
P_2O_5	·18
FeS_2	·36
Cl	·78
	99·95
Less O for Cl	·18
Total	99·77

Not found, F, ZrO_2, CO_2, Li_2O, SO_3, BaO.
A doubtful trace of Fe_7S_8.

11017.

SiO_2	73·80
TiO_2	·23
ZrO_2	·04
Al_2O_3	11·90
Fe_2O_3	1·90
X	·04
FeO	1·91
MnO	·12
CaO	.30
MgO	.33
K_2O	4·93
Na_2O	5·05
H_2O 105° C.	·04
H_2O above 105° C.	·13
Total	100·72

X "Rare Earths," Ce, Th, etc. Possible traces of P_2O_5 and Li_2O.

IV.—PALÆONTOLOGICAL WORK.

E. T. Newton. The Palæontological collection has been increased during the year by upwards of 4,000 specimens, collected by the officers of the Survey, or acquired by presentation and purchase. A detailed account of the presentations is given in the List of Donations to the Museum published in the Report for the year

1904, but there are a few which may be especially mentioned, namely :— Mr. E. T. Newton

Three specimens of *Prestwichia rotundata*, from the Coal Measures of Barnsley; a fine example of *Plesiochelys valdensis*, from the Wealden of Sandown Bay; a series of invertebrate fossils from the older Palæozoic Rocks of Haverfordwest; an example of the extremely rare *Fayolia* from the Coal Measures near Ilkeston; and four specimens of *Palæoxyris* from the Coal Measures near Dudley.

The following are the fossils which have been received from the officers of the Survey.

1. *Palæozoic.* Mr. Barrow has sent Devonian fossils from Bodmin; Mr. T. C. Cantrill, Old Red Sandstone and Carboniferous Limestone from South Wales; Mr. E. Dixon, Old Red Sandstone, Carboniferous Limestone and Coal Measures from South Wales; Mr. E. T. Newton, Silurian from Lemington; Mr. Clement Reid, Silurian and Ordovician from Cornwall; Mr. A. Strahan, Old Red Sandstone and Carboniferous Limestone from South Wales; Mr. H. H. Thomas, Ordovician from South Wales; Mr. W. A. E. Ussher, Devonian from Devon and Cornwall. Mr. J. Pringle has collected Carboniferous fossils near Leek; Coal Measure Plants etc., in North Wales, and Ordovician and Old Red Sandstone in South Wales. Mr. D. Tait has collected Carboniferous fossils in North Staffordshire.
2. *Mesozoic.* Mr. G. W. Lamplugh, Cretaceous fossils from Seend and Devizes; Mr. C. B. Wedd, Jurassic from Isle of Skye; Mr. H. B. Woodward, Lias from Somerset and Dorset; Mr. T. I. Pocock, Gault from Berks; Mr. Lamplugh, Portlandian from Oxfordshire and Bucks. Mr. J. Pringle has collected Rhætic and Lias fossils in Somerset, and Mr. D. Tait, Jurassic from the Isle of Eigg.
3. *Cainozoic.* Mr. Clement Reid, Eocene from Barton, and Mr. J. Pringle, London Clay from below Hyde Park.

Mr. R. Kidston, in the progress of his work on the distribution of Coal plants, has named a large proportion of the plants included in the above series. Among these plant remains Mr. D. Tait has detected some portions of wings of insects, which, although fragmentary, are exceedingly interesting; and it is hoped that more perfect specimens may be found which will permit the definite determination of these remains. The Invertebrata have for the most part been determined by Dr. F. L. Kitchin, in addition to a collection of Carboniferous Limestone fossils from Breedon and Ticknall kindly lent to the Survey by Mr. H. Vassall. The Vertebrata have been examined by Mr. E. T. Newton. Among the specimens collected from the Marine bed at Smallthorne Dr. Kitchin recognised a new species of *Pleuronautilus* which it is hoped will be shortly described by Mr. G. C. Crick

E. T. on. of the British Museum, to whom we are indebted for help kindly given in several matters relating to the Cephalopoda.

The revision of the Jurassic Mollusca contained in the Museum has been continued by Mr. H. A. Allen, who has completed this work for the Lamellibranchiata of the Inferior Oolite, Fuller's Earth, Stonesfield Slate, Great Oolite, Forest Marble, Cornbrash, Kellaways Rock, Oxford Clay and Corallian Rocks. A catalogue of the type and figured specimens from these formations has also been made, but it is not quite ready for publication. A catalogue of the type and figured Lamellibranchiata from the Rhætic and Lias will be found as an appendix on pp. (172–177).

The nomenclature of the Jurassic Vertebrata contained in the recesses on the west side of the Upper Gallery has been revised, and the whole series re-arranged and catalogued by Mr. E. T. Newton.

The revision of the nomenclature of certain groups of fossils in the Museum is now being carried on by specialists. Mr. Philip Lake, of Cambridge, is continuing his work on the Cambrian and Silurian Trilobites; Miss E. M. R. Wood, of Birmingham University, is making good progress with the Graptolites; and Dr. C. A. Matley has begun his examination of the Cambrian and Silurian Brachiopods. Dr. G. J. Hinde was good enough to undertake, and has now completed, the revision of the Sponges.

During May Mr. Newton visited Derby for the purpose of examining the large series of bones recovered from the Hoe Grange Cave at Longcliffe and securing a typical series for this Museum. An account of this Cave and its contents has been published by Mr. Arnold Bemrose and Mr. Newton in the *Quart. Journ. Geol. Soc.*, vol. lxi., p. 43.

A short account of the Triassic fossils preserved in the Museum was supplied by Mr. Newton to the British Association and has been published in their Report for 1904, together with similar information received from other sources.

A collection of Mesozoic fossils obtained by Mr. T. D. La Touche and Mr. P. N. Datta in Burmah was examined for the Geological Survey of India by Dr. F. L. Kitchin and a short preliminary report sent to Mr. La Touche.

The fossil collector, Mr. J. Pringle, has been occupied in the field for about five months, partly in obtaining plants from the Coal Measures for Mr. Kidston's work, and partly in collecting older Palæozoic fossils for the Survey officers in South Wales. Mr. D. Tait, the fossil collector of the Scottish Survey, has been occupied for about three months in collecting Coal plants in North Staffordshire, and in otherwise assisting Mr. Kidston in the work he is doing for the Survey.

The Survey collection of Fossils has been well used by Palæontologists and the following is a list of the Museum specimens which have been figured and described during the year.

In the PALÆONTOGRAPHICAL SOCIETY'S Volume for the year 1904. Mr. E. T. Newton.

Cretaceous Lamellibranchia, Vol. II., Part 1.

By Mr. H. Woods, M.A.

Lima Galliennei, *d'Orb.*, pl. ii., fig. 1, p. 3.
——— subovalis, *Sow.*, pl. ii., fig. 4, p. 5.
——— scabrissima, *Woods*, pl. ii., figs. 8, 9, p. 7. (Two specimens.)
——— (Plagiostoma) Meyeri, *Woods*, pl. iv., fig. 2, text-figure 4, p. 15. (Two specimens.)
——— (Acesta) longa, *Roemer*, pl. v., fig. 12, p. 25.
——— (Mantellum) *sp.*, pl. vi., fig. 16, p. 40.
——— (Limatula) tombeckiana ? *d'Orb.*, pl. vii., figs. 7–10, p. 45. (Four specimens.)
——— (Limea ?) composita, *Sow.*, pl. vii., figs. 24–26, p. 53. (Three specimens.)

British Carboniferous Lamellibranchiata, Vol. II., Part 3.

By Dr. Wheelton Hind, B.S., F.R.C.S.

Palæoneilo carbonifera, *Hind*, pl. xxii., figs. 8, 8*a*, *b*, p. 142.
Paracyclus du Noyeri, *Portl.*, pl. xxii., fig. 9, p. 163.
Solenomorpha major, *Hind*, pl. xxii., fig. 1, p. 158.

In the QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, Vol. LX.

By Mr. E. T. Newton, F.R.S.

Edestus triserratus, *n. sp.*, pl. i., and text-figures, pp. 1–9.

In the GEOLOGICAL MAGAZINE, 1904.

By Mr. G. C. Crick, A.R.S.M.

Pericyclus fasciculatus, *M'Coy*, p. 31.

In the JOURNAL OF THE ROYAL MICROSCOPICAL SOCIETY, February, 1904.

By Dr. G. J. Hinde, F.R.S.

Porosphæra globularis, *Phill.*, pl. ii., fig. 9, pp. 1–25.

In the PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY, London, ser. B., Vol. CXCVII.

By Mr. A. E. N. Arber, M.A.

Alethopteris lonchitica, *Schloth*, pl. xx., fig. 15, p. 305.

V.—MUSEUM OF PRACTICAL GEOLOGY.

A. The total number of visitors to the Museum during the year has been 62,934. This is the highest attendance yet recorded and is 8,064 higher than the record for the last normal year. The increase is in part due to the fact that the Museum is no longer closed during the month of August.

A duplicate of the geological model of the Isle of Purbeck, the original of which was sent to the St. Louis Exhibition, has been prepared for the Museum. The district is one in which the surface configuration and the form of the coast are closely related to the geological structure. The nature of the relationship is very clearly brought out in the model which will, therefore, prove to be of considerable use to students.

A temporary exhibit to illustrate the mode of occurrence of tin in Scotland has been placed on the main floor, and a case arranged to illustrate the petrological characters of road-stones has been set up in the entrance hall.

In last year's " Summary " reference was made to an important collection of British minerals which Mr. Rudler had arranged in twelve table-cases on the main floor. During the past year Mr. Rudler completed a Handbook to this collection which is now on sale. It contains a large amount of information with regard to British minerals, and will be found to possess a permanent value quite apart from the collection to which it refers.

II.—SCOTLAND.

I.—FIELD WORK.

I.—West Highland District.—Glencoe, Glen Etive, Glen Creran, and Knapdale, Argyllshire.

Mr. C. T. Clough, M.A., District Geologist.
Mr. J. S. Grant Wilson.
Mr. H. B. Muff, B.A.,
Mr. G. W. Grabham, B.A., } Geologists.

HIGHLAND METAMORPHIC ROCKS.

The tract embracing Glencoe, Glen Etive and Glen Creran in Sheet 53, forms part of the mountainous region on the east side of Loch Linnhe, which, in the Royal Forest, rises to a height of over 3,700 feet. It is trenched by deep and narrow valleys flowing west into Loch Leven and south-west into Loch Etive and Loch Creran.

Glen Creran Area.—The metamorphic rocks of clastic origin in this area, occur in the following descending order :— Mr. Wilso

(6.) Schichallion Quartzite in contact with Nos. 5, 4, 3, 2, & 1.
(5.) Black Schist with grey quartzite.
(4.) Lismore Limestone.
(3.) Black Schist.
(2.) Appin Limestone.
(1.) Ardrishaig phyllites.

Disregarding minor folding the general strike of the beds is N.N.E. and the dip westerly. The original clastic character of many of the beds is well preserved.

From the head of Loch Creran in Invercreran, Mr. Kynaston traced a well marked zone of limestone of the Loch Awe type.* It now appears, from the evidence on the hill slopes to the east of Ellerig, that this zone consists of two distinct limestones, No. 2 and 4, separated by a band of black schist (No. 3). At Ellerig, grey Ardrishaig phyllites (No. 1) with flaggy bands, occupy the valley bottom and extend for some distance up the western slopes, which are succeeded by a white crystalline limestone (No. 2), underlaid by calcareous phyllites. This is the "white limestone" of Appin, which is probably the equivalent of the brown dolomitic limestone that, in Mid Argyll, occurs near the top of the Ardrishaig phyllites. It is surmounted by a bed of black schist (No 3) followed in order by the "Lismore Limestone." † (No. 4) which, in this locality, is a bluish grey crystalline rock with impure dark calcareous band and is associated with black schist (No. 5) extending for some distance to the west.

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* Summary of Progress for 1900, p. 36.
† Annual Report, *Geological Survey*, 1896, p. 20.

. Wilson. The banded series of black schist and grey quartzite, described by Mr. Kynaston*, is well developed on the west side of the Creagan ferry and extends for a short distance along the western slopes of Glen Creran. This grey quartzite is evidently not the Schichallion quartzite but rather the northern prolongation of the quartzite, which, in S.E. Appin, is associated with the black schist.

To the N.W. of Ellerig and as far as the ridge between Allt Eiludh and Gleann an Fiodh there are numerous inliers of the Schichallion quartzite, often very pebbly, and in different localities in contact with each of the following groups, Ardrishaig phyllites Appin Limestone, Black Schist, and Lismore Limestone, as if unconformable to them.

On the west side of the hill path between Glen Creran and Ballachulish and near to the summit level, a tongue of the Ballachulish granite has invaded the schists and produced marked contact metamorphism. About half a mile from the margin of this intrusion, spots first begin to appear in the black schist, and towards the granite they gradually increase in number, and at the same time the rock becomes indurated. At a short distance, varying from 200 to 400 yards, from the granite, the spots disappear and this rock passes into a dark biotite hornfels. The quartzite in contact with this granite shows little alteration, but in the Lismore Limestone near to the granite, crystals of actinolite, etc., have been developed.

On the east side of Glen Creran, and to the north of Glen Ure, the schists are all hornfelsed and altered into a dark grey biotite schist, by the Ben Cruachan granite.

r. Muff. *Glencoe to Dalness Area.*—The mapping of the schists between Glencoe and Ballachulish has shown that the whitish (Appin) limestone of the Bridge of Coe, mentioned in last year's Summary of Progress, is continuous with the white limestone to the south of Ballachulish, and that this belt of limestone separates the black slates of Ballachulish from the greenish Ardrishaig phyllites. The last named group of rocks was traced southwards towards Glen Etive and was found to occupy an extensive tract. The metamorphism increases in an easterly direction between Ballachulish and Glen Coe and also in a southerly direction, and new minerals make their appearance. In Gleann Leac na Muidhe south of Glencoe, small blades of actinolite are found in the phyllites, and they increase in size and number in a south-easterly direction. Garnets are also found, more particularly along the edges of quartzose bands. Biotite, in addition to white mica, is developed in scattered scales in bands. The Ardrishaig phyllites are bordered on the side opposite to that on which the white (Appin) limestone occurs by a belt of garnetiferous mica-schist, which is continuous with a belt of that rock mapped by Mr. Kynaston, to the south. Beyond the garnetiferous mica schist the phyllites recur and are followed

* Summary of Progress for 1900, p. 35.

by a white quartzite similar in many respects to that of Glencoe, mentioned in last year's Summary of Progress, p. 67. To the south of Glencoe the foliation of the schists maintains, on the whole, a general N.E., and S.W., direction and dips towards the N.W., at angles seldom approaching the vertical. The beds are thrown into short sharp folds, the axial planes of which are inclined to the N.W. at rather low angles. A strain-slip cleavage is often well brought out by the quartzose bands. The micaceous minerals lie parallel to the planes of this cleavage; in fact the foliation of the district appears to be developed along the planes of a strain-slip cleavage. Mr. Muff.

Beinn Ceitlein Area. (East of Glen Etive.) Near the foot of the north-west side of this hill (2,731 feet) the patches of Highland metamorphic rocks which are preserved among the later igneous intrusions are indicated in the following table, in the relative positions in which they are now generally found, though the original order of succession is not apparent. Mr. Clough

1. Garnetiferous mica schist.
2. Band of mica schist, without garnets, probably only a few feet thick.
3. Calc-silicate hornfels.
4. Thin band composed of alternations of mica schist and siliceous schist, in places hardly represented.
5. Quartzite or quartzite schist, finely banded near the margin.

The calc-silicate hornfels is full of pale green prisms and a massive white silicate, macroscopically resembling diopside, and contains very little carbonate. It is intensely folded along axial planes striking north-east and south-west, but it seems probable that the original thickness was not less than 15 or 20 feet. It must have been plicated before the intrusion of the neighbouring granites, and subsequently hornfelsed by these granites.

The garnetiferous mica schist includes, in places, various thin seams containing dark green actinolite, sometimes arranged in radiate forms, in a matrix of mica schist, with abundant flakes of biotite. The garnets are usually surrounded by dark rims, partly composed of biotite, and elongated in a definite direction, thus showing that the rock has been considerably sheared since the garnets were developed. Indeed, it seems to follow that the period of metamorphism, during which the garnets were formed, must be earlier than the intrusions of the neighbouring granites, which are very rarely in a sheared condition. During these intrusions, however, the rock acquired the hornfelsed character which it now often shows. In one slide (11,785) cordierite or its weathered representative pinite is very abundant.

In ascending Beinn Ceitlein from the exposures of calc-silicate hornfels referred to, we pass over a considerable area of garnetiferous mica schist, which is followed immediately by quartzite without the intervention of any calc-silicate band. The absence of the latter is no doubt due to a powerful fault, which is

Ir. Clough. crossed by many later intrusions. Rather more than 700 yards E.N.E., of Stob Dubh—the south-west spur of Beinn Ceitlein—the amount of throw of this dislocation must be at least 500 feet, though there is hardly any crushed rock visible. Here one of the later dykes follows the course of the fault, which is nearly at right angles to the usual direction of the dykes, for about 200 yards.

The metamorphic rocks on the top and south-east side of Beinn-Ceitlein are almost entirely composed of quartzite, the general strike of which is nearly north and south and the dip west. The quartzite itself displays no clear evidence of alteration by the neighbouring granites, etc., but occasionally there are thin intercalations of mica-schist which contain small "knoten." In one locality, also, crystals which macroscopically resemble andalusite were found in one of the seams.

Knapdale District between the Sound of Jura and Loch Fyne.

Only a small area of Knapdale, forming part of the promontory between Loch Sween and Loch Caolisport (Sheet 28) was mapped during last season. Some of the intervening ridges running parallel with these sea-lochs rise to a height of 900 or 1,000 feet. The metamorphic sediments, together with the sheets of altered igneous rock, most of which probably represent intrusive sills, have there been thrown into numerous folds, the axial planes of which generally strike N.N.E., and dip W.N.W. As the original relations of some of the sedimentary beds were not ascertained, only a brief description will now be given till more of the adjoining ground is mapped.

Mr. Clough and Mr. Grabham. *Achahoish and Ellary.*—The rocks of sedimentary origin between Achahoish, at the head of Loch Caolisport, and Ellary on the west side of that sea-loch, consist for the most part of bands of phyllite of a greenish grey colour, alternating with fine-grained quartzites or quartz-schists. Thin seams of a calcareous and siliceous character, often showing small clastic grains, and thin bands of impure ferruginous limestone also occur. In the western part of the area the more siliceous beds are very little altered, and often show many clastic grains, but never become coarsely pebbly. Thin bands of a calcareous conglomerate, containing pieces of blue quartz, impure limestone, and occasionally of quartzite, have also been mapped for short distances on Maoile Fhuar, Eilean nam Muc, and near Stronefield.

Castle Sween and Kilmory Bay.—The coast between Castle Sween and Kilmory Bay, on the east shore of Loch Sween, shows a series of rock exposures consisting of pebbly quartzite and grey phyllites with stretches of sandy beach between. Eastwards, the ground is occupied with bands of epidiorite, grey pebbly quartzite and phyllites, the two former making ridges trending N.N.E., and S.S.W., with narrow intervening valleys in which lie the softer sediments.

In the bottom of the Kilmory valley, at the foot of the Cnoc Stighseir, the folded phyllites appear to pitch below the quartzite,

but the horizon of these phyllites has not been definitely proved. The pebbly quartzite with its boulder bed forms the northern promontory of Kilmory Bay, where it is overlaid by the basement beds of the Ardnoe group (a subdivision of the Argyllshire quartzite), comprising dark grey phyllites with clastic grains of quartz, limy phyllites and fine-grained quartzite, well exposed on the south side of that bay. Here they have been thrown into a series of synclinal and anticlinal folds which pitch in a N.N.E. direction at angles varying from 20° to 40°. Between the base of these beds and Port Ban, there is about 120 feet of light brown grey and gritty quartzite beds which become more pebbly as we approach the Port. On the north side of this inlet lies a boulder bed, about 16 feet thick, with pebbles of grey limestone, white and blue quartzite, white and pink felspar, phyllite and a few black schist fragments, which are all well rounded and enclosed in a siliceous matrix. The upper portion of this boulder bed gradually looses its foreign pebbles and passes into a gritty quartz-schist, while at the base in the coast section there is a thin brown limestone, the horizon of which has not been proved. Mr. Wilson

From Port Ban south to Port an Aomaidh the sediments consist of sandy and limy phyllites with thin quartzose bands sometimes repeated by folds. Between Port an Aomaidh and Point of Knap, the phyllites are associated with a series of fine-grained white quartzite bands which contain no pebbles. To the S.W. of Balliemore one of these quartzite bands is associated with a peculiar boulder bed, the matrix of which is a foliated calcareous schist with clastic grains of quartz. The bulk of the bed is composed of semi-rounded pieces of a cream-coloured limestone along with a few pebbles of black limestone and phyllite, some of which are well rounded and others subangular.

OLDER IGNEOUS ROCKS IN THE METAMORPHIC SERIES.

Knapdale Area.—On the promontory between Castle Sween and Achahoish the bands of epidiorite or chlorite schist, which undoubtedly represent altered igneous rocks, are, in certain areas, almost equal in bulk to the altered sediments. They occasionally cut the bedding planes of the latter, and their petrological character, in some cases, likewise suggests that they are intrusive. Some of the less sheared varieties show a distinct ophitic structure. Certain bands contain felspar phenocrysts which have not been much deformed though the matrix is thoroughly schistose. Messrs. Clough, Wilson, and Grabham.

OLD RED SANDSTONE.

Volcanic Rocks of Lower Old Red Sandstone age, with some intercalated sediments.

Glencoe to Dalness Area.—The boundary fault, that truncates the Volcanic Series of Glencoe on the west, was traced southwards towards Glen Etive. In Glencoe the volcanic rocks dip steeply Mr. Muff.

r. Muff. eastwards away from the fault, but on the western spur of Bidean nan Bian, where the fault changes its direction from N. and S. to N.W., and S.E., the basic andesites become vertical and finally turn over, so that they rest in inverted order on the rhyolites near the summit of Stob Coire nam Beithach.

r. Clough. *Beinn Ceitlein Area.*—From the bed of the River Etive near Dalness a narrow strip, composed of volcanic rocks and intercalated sediments, with numerous dyke intrusions, extends to the northern end of Beinn Ceitlein, to a height of more than 2,000 feet. The members of the series, for the most part, lie at gentle angles or are flat, so that the younger rocks are reached, one after the other, on ascending the hill.

The lowest group, about 500 feet thick, consists of andesitic lava flows and ash beds, with a thin basal breccia resting on quartzite, and appearing on different stratigraphical horizons. Some of the lava flows show pillow-form structure. The vesicles, and also various irregular veins which cross the lava form rocks, are often filled with epidote, and occasionally with white fibres which resemble tremolite. Both the fibres and the epidote were probably formed during the alteration effected by the neighbouring granite, and their presence seems to indicate that the lavas were considerably decomposed, and crossed by strings of carbonate, before the intrusion of the granite.

The middle group, probably about 300 feet thick, is composed of breccias and ashy sandstones, etc. The former vary in character from place to place; angular pieces of quartzite being the dominant constituent in some localities, and pieces of andesite in others. Some of the beds are rather fine-grained and siliceous.

The highest members of the series are composed of rhyolitic rocks of great thickness—probably not less than 1,000 feet. In certain weathered exposures many of them show included fragments, but no vesicles or distinct flow structures are seen. At present it is doubtful whether they should be regarded as ash beds or as lava flows with inclusions, or whether both of these types may not be represented.

The volcanic series with the associated sediments just described is bounded on the north-east side by the granite, and for a considerable distance on the south-west by a plane of crushing, nearly vertical or inclining steeply north-east, which separates the volcanic rocks from the quartzite. This line of movement is of considerable interest, for the crushed material found along it has a very compact, dark grey or black flinty character, resembling that observed in movement planes in the Cheviot granite,* and also in many Pre-Torridon crush-lines in the North West Highlands. Though later than the trachyte rocks on the north-east side, it is evident that this plane of movement is earlier than many of the dykes, some of which cross it without deflection, while others follow its path almost at right angles to their usual direction.

* "The Geology of the Cheviot Hills." *Geol. Survey Mem.* pp. 22–24.

Mr. Clough

The unevenness of the floor on which the volcanic series rests is admirably seen on Beinn Ceitlein. Near the base of the hill, exposures of quartzite emerge in places from beneath the andesitic lavas and tuffs, and near the hill top, quartzite again appears overlaid by a thin rhyolitic breccia which there forms a local base to the volcanic rocks. The difference in level between the highest and lowest exposures of the quartzite on this hill, is probably rather more than 1,740 feet, and the average slope of the old land surface on which the volcanic rocks now rest, is calculated to be about 1 in 2.

Newer Intrusive Igneous Rocks.

Mr. Muff.

Glencoe to Dalness. The granitoid porphyrite, mentioned in last year's Summary of Progress (p. 71) as permeating the schists on the N. side of Glencoe, passes to the south side of the Glen and there swells out to form a large mass of porphyritic quartz-diorite or biotite granite which is cut through by the Fionn Ghleann to a depth of 2,000 feet. Southwards it forms a narrow irregular belt along the boundary fault of the Volcanic Series. The granite is a rather fine grained porphyritic rock with biotite, and sometimes appears to pass into a quartz-diorite. Everywhere it is full of inclusions of schist (chiefly quartzite.) The margin of the granite is in some places well defined, with a vertical or nearly vertical junction; in others the granite sends anastomosing strings and veins into the schists. In the former case the granite becomes, near its margin, a very fine-grained rock with porphyritic felspars.

The alteration of the schists (chiefly greenish phyllites) along the margin of the granite is most marked. They gradually lose their fissility and pass into a tough dark compact hornfels. Both the actinolites and the garnets appear to be destroyed.

A small boss of a basic rock allied to Kentallenite is intruded into the schists near the head of Gleann Leac-na-Muidhe, which show contact alteration, similar to that around the granite, though hardly so intense.

A large number of porphyrite dykes having the usual north-north-east trend, cut through the schists, the volcanic series and the granite. To the west of Cleann Leac-na-Muidhe dykes are less numerous, and the commonest type is not a porphyrite but a fine grained bluish lamprophyre, probably a vogesite.

Mr. Wilson

Glen Creran.—Not far from the top of the ridge between Allt Eilidh and Gleann an Fhiodh, and to the east of the hill track which crosses to Ballachulish, the valley bottom is occupied by a small oval area of biotite granite with abundant pyrite. The Ballachulish granite mass, which was examined some years ago by Dr. Teall,* and found by him to be a "hornblende granitite or quartz diorite,"

* Annual Report, *Geological Survey*, 1896, p. 21.

Mr. Wilson. sends a tongue from the head of Glen Duror across the watershed into Glen Creran. A specimen (11,364) from this tongue is described by Dr. Flett as follows :—" Diorite with pale green augite, brownish green hornblende, biotite and plagioclase. The accessories are apatite, sphene, and iron oxides, There is little orthoclase but quartz is abundant."

In Glen Creran there are six separate areas of augite diorite. The first, mapped by Mr. Kynaston, lies to the south of Glen Ure and pierces both the Ben Cruachan granite and the surrounding schists. The largest area of augite diorite is found to the east of Barnamuc, where it is associated with two bosses of Kentallenite, but the exact relation between these two rocks is at present uncertain. About a quarter of a mile to the north of the latter locality and to the east of Salachail, there is another area of coarse augite diorite, containing large crystals of pale augite and abundant plagioclase felspars, but no quartz. The margin is chilled and the surrounding Ardrishaig phyllites are hornfelsed. About two miles further up this glen, and to the south of Meall an Aodainn, the dark grey biotite schists are pierced by another mass of augite diorite, which contains conspicuous large green augite crystals scattered through a greyish white base. Had this rock been in a more convenient situation for transport it would doubtless have proved a valuable addition to the Scottish rocks used for ornamental purposes.

Within the limits of Glen Creran five separate masses of Kentallenite have been mapped; the largest occupying about half a square mile. The two which are intimately associated with the mass of augite diorite at Barnamuc, already referred to, are very similar in character. One of them is described by Dr. Flett as a typical Kentallenite. The edge rock of these intrusions, both in the river section and in the Allt Bharainn is fine grained, and a microscopic section (11,358) shows that the " rock is a porphyritic representative of the Kentallenite group, its chief characteristic being the scarcity or absence of biotite and the evidence of an approach to the lamprophyres rather than to the porphyrites." The other three masses are small; one is surrounded by the granite not far from the summit of the hill-path between Glen Creran and Ballachulish; another is situated a short distance to the west of the hill track; while the third is in the centre of the tongue of Ballachulish granite which passes into Glen Creran from the west.

Three different kinds of dykes are found in Glen Creran, viz., granite, porphyrite, and lamprophyre. One small dyke of granite is found near the edge of the Ballachulish granite and resembles that rock in petrological character. The porphyrite dykes are the most numerous but are confined entirely to the east side of the Glen and to Allt Eilidh. They vary in breadth from 40 to 80 feet, have a north-east and south-west course, and are easily traced as they form conspicuous ridges or hill slopes. The largest are

often in the form of sills which dip north-west about 50°, and they increase in number in a south-easterly direction towards the head of Glen Ure. The lamprophyre dykes, whose general direction is north-north-east and south-south-west, and average breadth about 4 or 5 feet, are chiefly confined to the west side of the glen. Mr. Wils

Dalness to Clach Leathad Area. Most of the granite mapped is continuous with that described by Mr. Kynaston as of the Beinn Cruachan type. The dominant rock is a hornblende biotite granite, which graduates, first into a biotite granite by disappearance of the horn blende, and finally to a quartz-felspar rock with occasional drusy cavities and almost no ferro-magnesian constituent. This last variety occurs frequently in the high ground and probably marks the upper part of the original intrusion. A more acid granitic rock, consisting chiefly of bluish quartz and pink felspar with very little mica, forms a band, often from 100 to 200 yards broad, which passes from the southern end of Beinn Ceitlein to the northern side of Meall Odhar. It is later than the adjoining granite of Beinn Cruachan type and cuts both it and its aplite veins, and also some of the dykes of the district, but it is earlier than most of the porphyrite dykes. The visible margins are not chilled, but in one place it seems to pass into a quartz felsite dyke. Mr. Clou and Mr. Grabham

The dykes, which cut the schists, the contemporaneous igneous rocks and the granite of Ben Cruachan type, occur in such numbers that over a considerable part of the area they form half the rock, though the breadth of individual dykes rarely exceeds 30 yards and is generally less than 10 yards. These dykes vary in character from microgranite and quartz-felsite on the one hand to basic varieties resembling diorite and giving a specific gravity as high as 2.81. The microscopical examination of the specimens collected has not yet been completed, but it seems tolerably clear that the porphyite type is the most abundant.

Numerous examples of composite dykes have been met with. In some cases the porphyrites cut the quartz-felsites, but one instance was found where a dyke of quartz-felsite is later than one of porphyrite.* It is worthy of note, that in this area, most of the basic dykes seem to be later than the more acid.

Basic Intrusive Rocks. Basaltic Dykes.

Glencoe Area.—Several basalt dykes having a north-north-west trend, and presumably of Tertiary age, were met with, one of which determines the remarkably straight course of the River Coe for a mile and a quarter above Achatriochatan. Mr. Muff.

Knapdale Area.—A few thin, fine-grained, basaltic dykes, trending west-north-west or north-north-west, or in some cases nearly north and south, occur on the promontory between Loch Sween and Loch Caolisport, and are doubtless of Tertiary age. Messrs. Clough, Wilson, a Grabham.

* An instance of the latter kind was also described by Mr. Kynaston in the Summary of Progress for 1897, p. 88.

Another broader dyke, trending east and west, is probably of older date.

PLEISTOCENE AND RECENT.

Mr. Muff. *Glencoe to Dalness.*—The striated surfaces on the ridges on both sides of the Fionn Ghleann, as well as the transport of boulders of all types of the volcanic series across the schist region to the west, prove a general westerly motion of the ice-sheet during the maximum glaciation. Boulders of granite were found on the southern flank of the Bidean nam Bian, at altitudes of over 3,600 feet, within 200 feet of the summit. On the lower flanks of the hills there is evidence of a later movement of the ice down the glens.

The River Coe, where it issues from Loch Triochatan, flows through a rock gorge, whose walls are water-worn nearly 20 feet above the stream. The present outlet is almost certainly a post-glacial one. The rest of the barrier consists of knobs of rock, partly covered with morainic drift, but there does not seem to be any room for a drift-filled channel, which, if excavated, would drain that loch. The rocky barrier consists of granite and indurated quartzite and phyllites, cut off on the upper side by the fault which bounds the volcanic series on the west, whereby soft phyllites are let down against the granite and indurated schists. The lake basin is excavated in these softer rocks.

Mr. Wilson. *Glen Creran.*—The whole of the glacial deposits are of morainic character. At the lower end of the glen are bare rock slopes, with here and there a covering of herbage and scrub timber. Above Ellarig the valley is much broader, and there is a considerable depth of morainic detritus, which extends nearly to the head of the glen.

The glacial striæ indicate a movement of ice in directions varying from 15° south of west to 40° west of south, due probably to the different pressures exerted at different times by the neighbouring streams of ice which passed down the Linnhe Loch, and by the ice which moved outwards from the moor of Rannoch.

Mr. Clough and Mr. Trabham. *Dalness to Clach Leathad Area.*—The glacial drift consists chiefly of morainic material, distributed unequally over the valley bottoms and lower slopes. On the quartzite near the top of Beinn Ceitlein (2,731 feet) glacial striæ occur, most of which are nearly east and west, but in the low ground near the head of Alltchaoruinn the striations are nearly parallel to the direction of the glen.

Knapdale Area.—The glacial deposits in the neighbourhood of Achahoish and Ellary consist chiefly of thin patches of stiff brown boulder clay lying between the outcrops of the harder rocks. Most of the glacial striæ run between south-south-west and west-south-west, the latter direction being generally found at the higher elevations where the influence of undertow along the valleys could not be great. On the west side of Gleann Cinn-locha, striæ occur with a north-west and south-east trend, which are probably

later than the others, and seem to indicate a movement in a south-east direction almost straight down the steep slopes on which they occur. Boulders of Glen Fyne granite and of quartz porphyry like that common on the north-west side of Upper Loch Fyne, are tolerably abundant on the shores of Loch Caolisport, and indicate a transport from the north-east. Mr. Clough and Mr. Grabham.

In the bed of Allt-Cinn-locha about a third of a mile below Lochhead, and not more than a few feet above ordinary high water mark, there is a glacial shell bed composed of dark grey loam, with abundant remains of shells.

In Gleann Cinn-locha there is an extensive gravel terrace which belongs to the 100-feet raised beach, and some smaller patches belonging to the same beach have been preserved south-west of Ellary. A rocky shelf belonging to a lower raised beach is often seen on the west side of Loch Caolisport, and is sometimes covered with gravelly deposits.

The glacial deposits near Castle Sween and Kilmory Bay consist of a thin stony boulder clay, found in the narrow north-east and south-west hollows. The glacial striæ are numerous and well preserved, and run between 10° south of west to 75° south of west, At certain localities the direction varies on the same rock surface. but this may be due to the varying pressure of the ice. Mr. Wilson

The 100-feet raised beach is entirely carved out of drift deposits, and where its inner margin reaches a rock face or headland, such as the northern promontory of Kilmory Bay, or the steep rock slopes on either side of the Point of Knap, this beach has left no record of its existence. The inference is that the halt in the uplift of the land at this period was a comparatively short one, compared with that during the formation of the 50-feet beach. From Castle Sween to Loch Caolisport the 50-feet raised beach forms a well-marked feature, being partly a terrace of deposition and partly of rock erosion.

ECONOMICS.

Glen Creran.—The district could carry a magnificent forest growth. The natural drainage is excellent, the climate mild, the glen well sheltered, and the soil is adapted for the growth of all classes of hardwood and pine frees. About 175 years ago some valuable plantations were laid down, which were not properly attended to. Good trees have, however, survived, as for instance, the line of handsome beeches alongside the River Creran at Ellarig, and the large pines and larches in Glen Ure. Mr. Wilson

Glen Etive.—This area is partly used as deer forest and partly as sheep ground. Mr. Clough and Mr. Grabham.

There are the remains of extensive forests of Scotch fir, which are said to have been destroyed in historic times. An attempt is now being made to plant part of the ground, and if care is exercised in the selection of the trees, it seems likely to succeed.

Messrs. Clough, Wilson and Grabham.

Knapdale Area.—Between Castle Sween and Achahoish, the highest ground surveyed does not much exceed 1,000 feet, but most of the district is of a rough rocky character, the hill slopes being steep and frequently lined with rocky scars of epidiorite. It provides feeding for sheep and grouse, but there is hardly any ploughed land except on the flat raised beaches and alluvium at Castle Sween, Kilmory, and the foot of Allt-Cinn-locha.

At Castle Sween there were several large plantations of excellent mixed timber which reached maturity and were cut down two years ago. Very little timber grows between Castle Sween and the Point of Knap, except in the sheltered hollows of the Abhainn Mhor. For several miles around the Point the ground is too exposed to the south-west gales to allow trees to flourish, and the scrub timber is all stunted and bent to the north-east.

The population is very sparse and entirely confined to low levels near the sea. The hill slopes being generally steep, there are few large peat mosses except on the hill tops, in situations so far removed from any habitation that they are not much used for fuel; coal being cheaply conveyed by sea from the Clyde.

Traces of copper pyrites have been noticed in thin strings in a few of the epidiorite masses, but these are of no economic value.

Some of the basaltic dykes and of the harder siliceous bands are quarried for road metal, but the amount required is not large. In the Castle Sween and Kilmory area the gravel of the 100-feet raised beach is chiefly used for this purpose.

2. North Highland District—Embracing Parts of Ross, Inverness, Elgin, and Nairn.

Dr. B. N. Peach, F.R.S., District Geologist.

Mr. L. W. Hinxman, B.A.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A, B.Sc.
Mr. R. G. Carruthers.
Dr. J. Horne, (Acting).
} Geologists.

HIGHLAND METAMORPHIC ROCKS.

Dr. Peach.

Strathconon and Glen Strath Farrar Area (Sheet 82).—The area surveyed comprises portions of the counties of Ross and Inverness, and forms part of the mountainous district between Strath Bran in the north, and Glen Strath Farrar in the South. This ancient tableland, whose highest peaks exceed 3,000 feet in height, is drained by the Meig, the Conon, the Orrin, and the Farrar, which flow east to the basin of the Moray Firth.

The greater part of the area is under deer forest and is thinly populated; the inhabitants being restricted to the narrow glens.

The rocks of the Metamorphic Series may be arranged in two divisions: (*a*) a complex group of acid and basic gneisses with

hornblende and biotite as prominent constituents, schists derived from ultrabasic material, eclogites and pyroxene rocks; the whole series resembling certain types of Lewisian gneiss of the N.W. Highlands: (*b*) the Moine Series, comprising quartz-biotite-granulites (*b*1), garnetiferous mica schists (*b*2), ("muscovite-biotite-gneiss".) Dr. Peach

Sills of epidiorite and lenticles of garnet-amphibolite, which strongly resemble some of the more basic bands in the gneisses of Lewisian type, occur in the Moine Series. Moreover, there are quartz-biotite-granulites associated with the Lewisian gneisses (*a*), which are indistinguishable in hand specimens, and under the microscope, from the typical Moine Schists (*b*1).

From the mapping of the region it is clear that the complex group of gneisses (*a*) were not intruded into the Moine Series (*b*), either before or after they had assumed their present structures, as the former do not send apophyses into the latter, neither is there any trace of an aureole of contact metamorphism around them. On the other hand it seems probable that the complex group of gneisses (*a*) are inliers of Lewisian or Archæan rocks, on which the altered sediments of the Moine Series (*b*) rest uncomformably, and that both groups were affected by the same movements which developed common planes of schistosity.

Strathconon and Glen Fhiodhaig Forest.—The rocks of the Moine Series (*b*) occupy the central portion of the district; the muscovite-biotite-gneiss of pelitic type (*b*2) forming the high ground of Meallan Buidhe and Bac an Eich, while the siliceous schists and flagstones (*b*1) compose the mountain ridges that rise on either side of the head of the River Orrin. The garnets and garnet-aggregates with white mica and quartz, that are so abundant in the coarse pelitic gneisses of Meallan Buidhe and Bac an Eich (*b*2) appear to belong to two generations. The aggregates are often drawn out into phacoids or even into strings along the planes of movement, while in the same rock perfectly idiomorphic garnets can be observed. Both may be attributed to the effects of dynamical metamorphism, but the latter must have been produced when the movements had practically ceased.* Mr. Hinxman.

The complex, acid, basic, and ultra-basic gneisses (*a*) occupy the hollow in which lies Loch Beannachan and cover a wide area on either side of Gleann Fhiodhaig. It is at once evident that these complex gneisses belong to the same series as those of the Glen Orrin inliers described in the Annual Summary for 1902, and referred to as the Lewisian gneiss. The predominant rock type in the Scardroy and Loch Beannachan area is a thoroughly granulitic, pinkish, felspathic gneiss with occasional thin folia of biotite, biotite-hornblende, and hornblende gneiss. In places the more basic bands increase in frequency, until the rock becomes a well-banded gneiss with rapid alternations of acid and basic material.

* See Lamplugh "Geology of the Isle of Man," pp. 110–114.

Dr. Hinxman.

Other rock masses enter into the complex, some of which may perhaps be regarded as early basic intrusions. Among these is the irregularly shaped mass of ultra-basic rock seen on the hillside above Loch Beannachan, ½ mile N. of Carnoch. The original rock appears to have been a hornblende-peridotite, but the greater part of the mass is sheared into a rock described by Dr. Flett as a talcose chlorite-tremolite-schist. Elsewhere the talc is scarce and remains of olivine occur in irregular grains, in whose cracks a meshwork of serpentine appears.

There are also bands of massive amphibolite and hornblende schist that follow a definite direction and can be traced for some distance through the gneiss. These may possibly represent early basic intrusions.

The steep crags and summit of Coire Bhuic, that rise to the S. and S.W. of the loch of that name, some two miles west of Scardroy, are, to a large extent, formed of hornblende gneiss, which here covers a considerable area of ground. Some parts of this mass show very little parallel structure, and the rock seems to be entirely made up of hornblende and large garnet aggregates. In other parts it is well foliated and tolerably felspathic. There are also many lines of shear along which the rock passes into a fine grained hornblende or chlorite schist. Portions of the rock contain much epidote, forming oval light-green patches mixed with felspar, which are very conspicuous against the darker green of the groundmass. Specimens from this locality have been examined by Dr. Flett, who describes them as hornblende gneisses and schists, sometimes garnetiferous. They contain little quartz, but consist essentially of dark green hornblende and plagioclase felspar, orthoclase or albite and accessory sphene. One specimen contains biotite, and another is rich in epidote as described above.

A conspicuous feature that closely follows the 1,000 feet contour along the slopes of Meallan Buidhe marks the boundary line between the Moine series (*b*) and the rocks of Lewisian type (*a*) on the south side of Loch Beannachan. The actual junction of the two formations can be seen in several of the small streams that fall down the steep hill-side into the loch. In most of these, the coarse pelitic gneiss (*b*2) is seen resting upon the acid banded gneiss (Lewisian), but in one case at least the former is in contact with a band of dark hornblende rock. At the point where this boundary line crosses the river Meig, a peculiar rock occurs at the base of the pelitic gneiss (*b*2), which is characterised by an abundance of hornblende in addition to biotite, and also by the occurrence of rounded knots or phacoids of gneissose material, distinct from the ordinary quartzo-felspathic-augen and suggestive of a derivative origin. This rock is seen in contact with the banded gneisses (*a*) at several points along the river below the bridge at Coire Bhuic, and also in the Coire Bhuic burn.

Dr. Carruth-

Proceeding north-westwards across Glen Fhiodhaig we find, on the spur which runs E.N.E. from Creag na h' Iolaire, the most acid

variety of the Lewisian gneiss (*a*) in contact with another member of the Moine Series, viz :—the siliceous Moine granulites, and the two rocks being intimately folded together, the boundary between them is difficult to trace.

Mr. Hinxman. Further to the west, and almost immediately to the N. of Creag na h' Iolaire, a belt of massive siliceous granulite (*b*1), several hundred yards in breadth and very uniform in character, caps the summit of the hill and sweeps down the crags into the bottom of Coire Bhuic. On the hill top and higher part of the precipice it is in contact with the hornblende gneiss (*a*) forming the basic mass described in a former paragraph, but near the foot of the crags it is associated with the normal acid banded gneisses of the Coire a' Bhuic burn. A still more striking instance of discordance between the two formations is seen half a mile further to the west. Here a narrow strip of quartzo-felspathic-granulite of regular Moine type (*b*) descends in a similar manner over the hill face into the corrie below. In its lower part it is in contact on both sides with garnetiferous hornblende gneiss (*a*) often showing very little foliation. On the west side above the 1,500 feet contour line, the Moine granulites (*b*1) are seen next to the finely-banded acid and basic gneiss (*a*) which is so well exposed along the most easterly head stream of the Allt Mhartuinn.

Mr. Hinxman. The Moine Schists (*b*) and the complex series of gneisses regarded as Lewisian (*a*) have now a common foliation which has, in most cases, obliterated any earlier planes of foliation that the latter may have possessed. At several localities, however, in this region, traces of an earlier foliation and system of folding have been observed in the Lewisian gneisses, which do not pass into the contiguous Moine granulites.

Mr. Carruthers. West of the area just described, Mr. Carruthers has obtained additional evidence, on both sides of Glen Fhiodhaig, regarding the petrographical characters of the Lewisian type of gneisses (*a*) and their relation to the Moine Series. About four miles south-west of Loch Beannachan the boundary between the former and the siliceous Moine Schists (*b*1) is well defined, and has been traced across that valley and for some distance to the north, where the strike of the common foliation is N. 5° to 10° W. At one locality in the river Meig, a thin band, composed of quartzo-felspathic phacoids, probably representing a conglomerate, intervenes between the hornblendic gneisses (*a*) and the siliceous schists (*b*1). Again, further down the valley, the complex series of gneisses (*a*) appear to underlie a folded mass of muscovite biotite gneiss (*b*2) with idiomorphic garnets.

Dr. Peach. The complex series of gneisses of Lewisian type (*a*) in the basin of the Meig which have just been described are the southern prolongations of a large area of the same rocks south of the River Bran, previously mapped by Dr. Peach, and referred to in the Annual Reports.* In his descriptions he notes the occurrence of acid, basic,

* Report of the Geological Survey, 1895, pp. 19–20. Summary of Progress for 1898, p. 7.

and ultrabasic rocks, and correlates them with Lewisian gneisses in the west of Ross-shire, and he further suggests their unconformable relation to the younger and overlying series of Moine Schists.

Mr. Anderson. *Glen Strath Farrar.*—Southwards, in Glen Strath Farrar, Mr. Anderson mapped gneisses of Lewisian type which are probably the southward extension of similar rocks in Glen Orrin, described by Mr. Hinxman in the Summary of Progress for 1892, p. 88.

The more basic rocks are usually hornblende schists with subordinate quartz and felspar: but a little green augite may also be present, and in some small patches biotite partly replaces the hornblende. Bands of actinolite schist have also been found. As in the valley of the Meig, the marginal phase of the acid variety of the Lewisian gneisses (*a*) is here extremely like the surrounding siliceous schist of the Moine series—a resemblance which is borne out by microscopical examination. In the more central portions, however, the acid bands of the Lewisian group apparently become more felspathic, and may represent sheared pegmatites.

The rocks of the Moine Series (*b*) vary in character from typical muscovite-biotite-gneiss (*b*2) to highly siliceous schist (*b*1). Near Ardchuilk there is an alternating series of thin micaceous and siliceous bands between the muscovite-biotite-gneiss (*b*2) and the siliceous schists (*b*1).

The strike of all these schists in the neighbourhood of Ardchuilk, and northwards almost to the watershed, is nearly north and south, but westwards, and south of the River Farrar, it swings round to the south-west. The inclination is nearly vertical. A kind of striation or striping is very commonly developed on the bedding planes; which is remarkably persistent in direction all over the area. Where the schists strike north and south this striation dips to the south at an angle usually greater than 45°; where the strike is south-west, the striation also dips to the south-west. A parallel striation has been observed in the contiguous series of Lewisian gneisses.

Dr. Crampton. *West Monar Forest.*—Dr. Crampton has also mapped representatives of the Lewisian gneiss and the Moine series, west and north-west of Loch Monar. The quartzo-felspathic and hornblendic gneisses of the former group, which have a limited development, are coarsely banded, and different types of rock alternate rapidly. The acid varieties appear to be more felspathic and granitic than the quartzose Moine schists, and are accompanied by bands rich in biotite and others containing hornblende. The junction of these rocks with the Moine series is nowhere well seen, but different members of the latter seem to be in contact with the gneisses of Lewisian type. The quartzose and pelitic sediments of the Moine series are here represented by granulitic, quartzo-felspathic and garnetiferous muscovite-biotite-gneisses. A wide band of the garnetiferous mica schist (*b*2), the western margin of which had been previously mapped by Dr. Peach, has been further traced. Its eastern boundary crosses Bidean an Eoin Dearg and Meall Mhor,

and the western boundary has been traced from Sgurr Choinnich to Bidean a Choire Sheasgaich, the strike being mainly N.E. and S.W. On either side of this band there is an alternating group of flaggy and siliceous gneisses followed on the east side by more massive quartzose gneisses. Dr. Crampton.

The metamorphic rocks of Strathconon and Glen Strath Farrar are traversed, in places, by intrusive igneous rocks which have shared in the foliation of the crystalline schists. Mr. Carruthers.

On the hill, one mile east of Cairngorm, north of Gleann Fhiodhaig, Strathconon, lenticular inclusions of hornblende-garnet-gneiss occur, both in the Moine Series and in the Lewisian gneiss. One of these, about 1¼ miles north-west of Creag na h' Iolaire, is massive and almost unfoliated in the centre, but at each end is sheared out in long tongues in the midst of the Lewisian gneiss.

In the West Monar Forest garnet hornblende schists of igneous origin occur as bands and as lenticular masses, chiefly along one line of strike, about the middle of the outcrop of the muscovite-biotite-gneiss. Dr. Crampton.

The zone of alternating siliceous and micaceous schist occurring at the margin of the muscovite-biotite-gneiss is marked in the Loch a' Mhuilinn district—Glen Strathfarrar—as elsewhere, by the presence of numerous little knots or lenticles of basic igneous rock, which are sometimes foliated. Two types are recognisable; one is a hornblendic rock without noticeable garnets, the other might be described as garnet-amphibolite. Pegmatites are also pretty common in this zone, and some of these are possibly of an intrusive type. Mr. Anderson.

FAULTS.

The principal structural feature in the region is the powerful line of dislocation which, as described in former reports, has defined the valley of the Meig between Milton of Strathconon and Inbhir-chorainn in the present map. From the latter point the fault follows the course of Gleann Chorainn, and, crossing the col at the head of that glen, is continued through the head of Glen Orrin and across the watershed between the Conon and Farrar to Loch Monar. The lateral movement which distinguishes this fault, in common with the other N.E. and S.W. dislocations of the district, is indicated by the torsion of the strata towards the fault, and the horizontal striae often visible on slicken-sided surfaces along the crush lines. Mr. Hinxman.

Another system of crush lines, nearly at right angles to that described above, crosses the area to the N.W. of Gleann Chorainn. The most important of these appears to be a continuation of the dislocation traversing Glen Docherty and Loch Maree. It crosses the watershed between the Meig and the Bran, immediately to the south of Carn Mhartuin, is well seen along the course of the burn to the E. of Carn Chaorain, and has probably been an important factor in determining the hollow in which lie the waters of Loch

Mr. Hinxman. Beannachan. Another of these crushes gives rise to the deep and picturesque gorge on the S.W. side of Meallan Buidhe, and several minor examples are found along the burns that fall into Gleann Chorainn.

Alladale, Freevater, and Amat Forests.
(Easter Ross.)

Dr. Crampton. A narrow belt of ground, in Easter Ross, was surveyed during the season in order to complete sheet 93. Forming, as it does, the north-east extension of the dissected table-land which culminates in Ben Dearg (3547 ft.), its dominant features are smooth-topped hills rising to a height of 2,000 feet. It is drained by the head streams of the Alladale and the Blackwater, flowing into the Carron, and those of the Abhuinn Dubhach, a tributary of the River Enaig, which, in turn, joins the River Oykell.

The rocks entering into the area are massive, flaggy, quartzose granulitic schists and garnetiferous muscovite-biotite-gneisses, of the Moine Series with thin sills of biotite-hornblende schist.

The prominent zone of pelitic gneiss (garnetiferous muscovite-biotite-schist), which has been traced more or less continuously in a N.N.W. direction across the western part of Sheet 93 from the Loch Luichart district to Glen Beag and Coire Mòr, changes its strike along the northern margin of that map and swings eastwards to near Alladale Lodge and across the River Carron, where it joins with a band of similar material, previously mapped by Mr. Clough south of Glen Calvie Lodge. The zone is much narrower near Alladale than north-west of that locality, which is probably due to the pitch of the folds, whereby the pelitic gneiss plunges underneath the quartz-biotite granulites.

Findhorn Area, embracing parts of the Counties of Inverness, Nairn, and Elgin.

Dr. Peach. The tract surveyed in Sheet 84 is traversed by the River Findhorn, which flows north-eastwards into the Moray Firth. Towards its western limit the hills rise above the 2,000 feet level along the watershed between the Findhorn and the river Nairn on the north, and the Dulnan on the south. The area is crossed by the hollow in which lies Loch Moy, between the Findhorn and the Nairn ; the southern extension of which forms the pass of Slochd Mor on the watershed between the Findhorn and the Dulnan. This valley is probably the remnant of a system of consequent drainage of which the Findhorn, above Tomatin, was once a tributary.

The crystalline schists of this area comprise both groups of the Moine series, quartz-biotite-granulites and muscovite-biotite-schists.

Dr. Horne. *Area west of Loch Moy and the Findhorn at Tomatin.*—The flaggy granulitic gneisses are best seen on Meall Mor—1,611 feet—a ridge with numerous rock exposures about two miles W.N.W. of Moy Station, where they are pierced by knots and veins of granite and pegmatite within half a mile of the granite margin. On that ridge

the strike of the foliation is north-west, that is, roughly parallel to the trend of the granite boundary. The muscovite-biotite-schists appear as narrow bands interfolded with the flaggy granulitic gneisses, as for instance on Tom na Ulaidh west of Invereen on the Findhorn, on Carn an Loin south of Loch Moy, and other localities. It is noteworthy that close to the granite margin, the flaky type of muscovite biotite gneiss is so permeated with granitic material that the one type of rock seems to merge into the other. This feature may be studied in the section in Lynemore wood, about half a mile south of Moy station. Dr. Horne

Area east of the Moy granite.—East of the granite mass of Moy the siliceous Moine schists and muscovite-biotite-gnesis are buried under drift and peat, and except in the stream courses and on the hill tops there are few rock exposures. The quartz-biotite-granulites form the dominant type, but belts of muscovite-biotite-gneiss also occur. Dr. Peach

A coarse flaser gneiss of pelitic type is well seen on the hill top ¾ mile E. by S. of Crofts, and along the course of the Allt Bruachaig immediately to the south, where it is often interfolded with fine-grained quartz-mica-granulites. On both sides of the gorge of the Findhorn at Polochaig these gneisses show a considerable amount of alteration, which may be ascribed to the Newer Granite. They are converted into an extremely coarse granitoid rock, in which wavy folia of felted deep-black mica in large crystals, much of which is probably of secondary origin, surround or separate phacoids and strings of granite material. This latter material appears to be distinct from, and of later origin than, the ordinary quartzo-felspathic veins and eyes that so often characterise the pelitic gneiss. So completely indeed is the gneiss impregnated with the granitic material that in places the rock closely resembles a coarsely foliated granite. The gneiss in the same locality is in addition traversed by numerous veins of acid granite and coarse muscovite- or muscovite-biotite-pegmatite that cross the foliation planes, and may be regarded as a later phase of the granite intrusion. Mr. Hinxman.

The belt of gneiss just described, which near Polochaig is over two miles broad, can be followed from the Findhorn southwards to the watershed with the Dulnan. Eastwards it reappears and forms the water parting between the Findhorn on the one side and the Dulnan and Dorback streams on the other, terminating abruptly near the upper end of Lochindorb. A second band of pelitic gneiss —probably a repetition by folding of the zone already referred to— runs northwards by the east side of Lochindorb, thence crosses the moors in a north-westerly direction, and following the gorge of the Findhorn from Banchor up to near Drynachan Lodge, passes north-westwards into the Nairn valley system. Dr. Peac Mr. Hin man, D Crampton, Mr. Ande son, Mr. Carruthers

The area enclosed between this ring of muscovite biotite gneiss and the Moy granite massif is mainly occupied by varieties of the quartz-biotite-granulites which, throughout the greater part of the tract, are invaded and altered by granite intrusions.

Dr. Crampton. In the tract south-east of Lochindorb, a band, consisting chiefly of garnet-hornblende-rock with hornblende and biotite gneiss, accompanied by massive pink felspathic gneisses, extends from Carn nan Gabhar, southwards by Cairn loch. Owing to *lit par lit* injection of granite material, some of these rocks are not easily separated from the contiguous granite veins and strings. This zone of hornblende-gneiss may probably represent the hornblendites and epidiorites so common in the Moine Series in Eastern Ross; but the association of rocks is strongly suggestive of Lewisian types of gneiss.

Newer Igneous Rocks.

Dr. Peach, Dr. Horne, Mr. Hinxman Part of the large mass of newer granite, extending from the hills east of Clava in the valley of the Nairn southwards across the watershed by Moy to the Findhorn, was mapped during last season by Messrs. Horne, Peach and Hinxman. Dr. Horne traced the western limit from Beinn a Bheurlach, west of Moy Hall south to the Findhorn, Dr. Peach, its eastern boundary from Ruthven on the Findhorn across the watershed to the north of Carn nan tri-tighearnan, while Mr. Hinxman surveyed the portion south of the Findhorn near Tomatin.

The prevalent type near Moy is a flesh-coloured biotite granite in which the orthoclase occurs as large phenocrysts with a moderate quantity of biotite and no muscovite. A more acid type appears in the hills W.N.W. of Moy, where biotite is more sparingly developed and muscovite is present with abundant quartz. From these phases there is a gradation to the grey variety, rich in biotite, with large phenocrysts of orthoclase and some plagioclase felspars, exposed in the granite quarry north of Moy Station. Further south, between Polochaig and the Dell of Morile above Tomatin, examples of the prevalent acid type are visible at Upper Inverbrough, in Allt na Frithe west of Tomatin Station, and at other localities. In that area also there is a gradation to basic varieties exposed in several isolated sections. On the hill slope W.N.W. of Croftdhu, on the east side of the Findhorn, the porphyritic granite merges into an even-grained, less acid type rich in biotite. Not far to the south, near Corrybrough, hornblende is associated with the biotite and plagioclase felspar is more abundant, and the rock becomes a quartz-biotite-hornblende-granite or tonalite. The best section of this basic variety (tonalite) occurs in the railway cutting east of Findhorn Bridge, where it is associated with the even-grained granite rich in biotite, and a passage from the one to the other can be traced.

Still more basic modifications of this plutonic mass occur in the basin of the Findhorn north and south of Tomatin. On the east bank of the Findhorn, less than half a mile above Polochaig, there is a small patch of diorite, composed of plagioclase felspar and hornblende, with brown biotite, iron oxides (with some leucoxene) and apatite as accessory ingredients. Dr. Flett, who has examined

a section of this rock, considers that most of the amphibole has formed from pyroxene, and thinks it doubtful whether any of the hornblende is primary. The rock thus has a resemblance to the epidiorites, but the felspar is not granulitised or recrystallised and retains its original rectangular outlines. Again on the bank of the Findhorn, about half a mile south of Findhorn Bridge, fine-grained diorite is exposed, which is evidently a more basic variety of the granite, though its relations to the tonalite further north are not visible. Dr. Peach, Dr. Horne, Mr. Hinxman.

Along the western margin of the granite the boundary is mostly buried under drift, but on the eastern slope of Meall Mor, two miles W.N.W. of Moy Station, the contact with the schists is visible. There veins of biotite granite pierce the flaggy gneisses, showing in some cases a rude parallel arrangement of the minerals. Veins of pegmatite with muscovite and biotite likewise traverse the schists near the margin of the granite. Again in the wood west of Tomatin Station, the penetration of the biotite gneisses by the granite is well seen, both being cut by veins of felsite.

A feature of the belt of schists in contact with the granite west of Moy is the occurrence of dykes of pink quartz-porphyry which, in some instances, appear as veins within the plutonic mass. Veins of lamprophyre are there of rare occurrence. They also appear in the area towards the north-east boundary of the granite, where they pierce both the granite and the schist.

Along the eastern margin of the massif a similar interfelting of schist and granite is observable, but the ground is much covered with peat and drift. On Carn nan tri-tighearnan, which is the centre of a large remnant of the old plateau, both granite and schist are so decomposed that they can easily be dug with the hammer: indeed large idiomorphic crystals of orthoclase derived from the porphyritic granite may be readily collected. Notwithstanding the decomposition the apophyses of the granite are seen to be cut by aplites and pink-coloured quartz-felsites with quartz in double pyramids.

East of the Moy massif the schists are more or less permeated with granite intrusions, some of which consist of biotite granite, while others contain both biotite and muscovite. Dr. Peach Mr. Anderson, Mr. Carruthers.

In the south-east part of Sheet 84, beyond Lochindorb, Dr. Crampton traced the western margin of a mass of granite which he believes to be the source of the veins and strings that traverse the adjacent schists. Dr. Crampton.

OLD RED SANDSTONE.

An outlier of Old Red Sandstone, belonging probably to the Middle or Orcadian division of that formation, part of which was previously mapped by Dr. Horne, occurs in the Findhorn basin at Drynachan Lodge. Forming a narrow strip about three miles long and a few hundred feet broad, which is bounded by two Dr. Peach.

Dr Peach. faults, it extends from a point near Daless in a north-east direction to beyond the Carnoch Burn.

Owing to a thick covering of drift there are few rock exposures, but in the streams that join the Findhorn near Daless and Drynachan, coarse breccias, containing angular and subangular fragments of schist and porphyritic granite, with thin intercalations of friable red sandstone, dip at a high angle to the N.W. In the Carnoch Burn, where the outlier is broadest, the breccia is not so coarse, and there is a greater proportion of sandstone. The inclination of the beds rarely exceeds 30° and there is a return dip near the N.W., margin, indicating that the strata form a trough, and suggesting that the faults decrease in a N.E. direction.

FAULTS.

The two sub-parallel faults bounding the Old Red Sandstone outlier just referred to, can be followed for some distance to the south-west. The one on its north-west margin, with the greater downthrow, has been traced to the Findhorn gorge at Polochaig and thence to Ruthven, where it is concealed beneath the alluvium of the Findhorn, but probably extends much further to the south-west. Between Polochaig and Ruthven it truncates the Moy granite massif for more than a mile; the schist in contact with the granite being much shattered. It is highly probable that this dislocation has indirectly determined the course of the Findhorn in a north-east direction by the Streens, and deflected the river from its old channel through the Moy valley.

There is a certain amount of evidence in favour of the opinion that crust movements still occasionally take place along these faults, as suggested by Dr. Charles Davison in his report on the Inverness earthquake of 1901.*

PLEISTOCENE AND RECENT DEPOSITS.

Mr. Hinxman. *Strathconon Area.*—The few striæ that have been observed, and the disposition of the carried boulders, indicate an ice-movement to east-north-east and north-east over the region. A local divergence or perhaps a later movement of the ice to the east-south-east, down the hollow between Carn Chaorain and Scardroy Lodge, is suggested by the numerous boulders of basic rock from the cliff of Coire Bhuic, found along the path that crosses the watershed to Achnasheen.

The fine series of lateral moraines seen at the head of Glen Orrin, up to a height of about 2,000 feet above sea level, are evidently not due to the local valley-glacier; but were laid down by an ice-sheet which passed eastwards out of Monar over the col at the head of the valleys.

The region under description, with the exception of a small portion reserved for sheep around Scardroy, is entirely deer forest.

* *Quart. Jour. Geol. Soc.* 1902, vol. lviii., p. 378.

The gneisses of Lewisian type, especially where the basic element is predominant, afford excellent grazing. Cultivation is confined to small patches of alluvial soil at either end of Loch Beannachan.

Glen Strath Farrar. In the area near Broulin Lodge, fully half of the surface is covered by accumulations of glacial origin. It is observable that slopes facing the west are generally covered with Boulder-clay, which is absent from those facing the east. In this region also there are wide-spread morainic deposits. Mr. Anderson.

For about a mile below Broulin Lodge the River Farrar flows through an alluvial plain that probably marks the site of an old lake. Further down, there are two parallel dry valleys, probably representing ancient channels of the river, formed perhaps while the present course was blocked in some manner by ice.

The Findhorn District.—The whole area, with the exception of the hill tops and rock gorges, is more or less covered with glacial deposits, divisible into:— Dr. Peach

(*a*) Boulder-clay, belonging to the older glaciation.

(*b*) Morainic deposits, representing the later glaciation, usually arranged in mounds, but merging into fluvio-glacial gravels, sands and silts of high terraces.

The Boulder-clay of this district is a stiff fawn-coloured deposit, full of well-glaciated blocks of local rocks, but containing fragments of red sandstone, breccia, and grey sandy shales foreign to the area. These foreign boulders are most numerous towards the north and gradually decrease in number towards the south and east. Thus, in the deep section of Boulder-clay laid bare by the Allt Dearg about 5 miles north-north-east of Loch Moy, they form about 30 per cent. of the included fragments over four inches in diameter; while, at the conspicuous scar east of Quilichan, 4 miles south-east of the former locality, they number 4 per cent. In the sections exposed in the Rhilean Burn two miles still further to the south-south-east, only an occasional boulder of red sandstone is to be found. The Boulder-clay has a much wider distribution than the morainic deposits. It fills the hollows sometimes to a depth of over 200 feet, and can be traced across cols at a height of nearly 2,000 feet to the east of Freeburn and Moy. Even the highest hill tops show some traces of the passage of the ice sheet either by means of striated surfaces or foreign boulders.

The evidence seems to point to the conclusion that the ice movement, during the deposition of the Boulder-clay, was generally northwards over the district. It varied from east-north-east, to about north-east, in the west, and from north-north-east to north, and even to a few points west of north, in the middle and south-east parts of the area, as if the ice from the Monadhliath range had been deflected by that from the Cairngorm Mountains.

The occurrence of Old Red Sandstone boulders in such numbers in the Boulder-clay, as well as their peculiar distribution, suggests that the ice before reaching the present area may have crossed the Great Glen.

MORAINIC DEPOSITS.

Peach. Over most of the area beneath the 1,750 feet level the boulder clay is usually overlaid by gravelly morainic matter, the included stones being similar to those found in the boulder clay. Striated blocks, however, are less common and many of the stones are well rounded and waterworn. The terraced shaped arrangement of the materials over wide areas, which consist in part of fine sand and silt, suggests that these deposits may have been largely distributed by the "melt water" from the ice itself, as well as by the ponding back of the natural drainage of the ice free areas along the edges and at the end of a retreating glacier. The distribution of these moraines and terraces points to the conclusion that the Findhorn Valley was occupied by a glacier, which, at its maximum, must have filled that valley below Freeburn and Moy to a height of at least 1,750 feet above sea level. After passing the constriction east of Moy it moved eastwards and eventually coalesced with the Nairn valley glacier on the one side and with that of the Dulnan and Spey on the other. The moraines and terraces mark successive stages in the retreat of the glaciers.

Cramp- South of Lochindorb the Dulnan glacier appears to have sent a lobe through the pass of Beum a Claidheimh where the road from Carrbridge to Nairn now runs. The sides of the pass are terraced with gravelly moraines which spread out over the plain to the north. About three miles north of the pass, a succession of dry valleys or rock notches, draining towards the east, cross the northern spur of Carn nan Clach Garbha in such a manner as to indicate that the Findhorn Valley glacier must have passed eastwards across this ridge and at one period have joined with the ice of the Dulnan and Spey glaciers. The rock notches are accompanied by a series of gravelly moraines, suggesting that each notch in turn acted as an outlet for the water escaping along the edge of the glacier during pauses in its retreat.

Carruth- In the upper part of the Leonach Burn about two miles west of the area just described, certain phenomena were observed which suggest that the drainage of that stream had been obstructed by a barrier which was lowered at intervals. The burn rises in high ground to the south, which shows no traces of the later glaciation, and appears to have been ice-free even at the time of the greatest extension of the Findhorn glacier. The valley below Badnonan and Knockdhu is crossed by a series of gravelly morainic mounds. Higher up it is floored with a deep deposit of sand and gravel arranged in flat-topped terraces and mounds, trenched at successive levels with stream courses, now dry, through which the water of the valley drained, as the barrier in front was being lowered. The ridge, ending in Carn a Garbh ghlaic, that separates this valley from that of the Rhilean Burn is terraced along its north-west face with moraines which swing round the front of Carn a garbh ghlaic and bend upwards into the valley of the Leonach Burn. The ridge is also trenched at different levels in such a way as to

suggest that the melting water from the Findhorn glacier poured over the lowest levels of the water-parting into the Leonach Burn.

In the ground north of the Rhilean Burn, terraces of moraines form rings round some of the hill tops, as if the latter had been temporary "nunataks" above the surface of the ice. Successive rock notches cross the western spurs of Carn Sguman just north of the Findhorn gorge near Carnach, which may probably have been eroded by the water escaping along the edge of the ice during its retreat. Mr. Anderson.

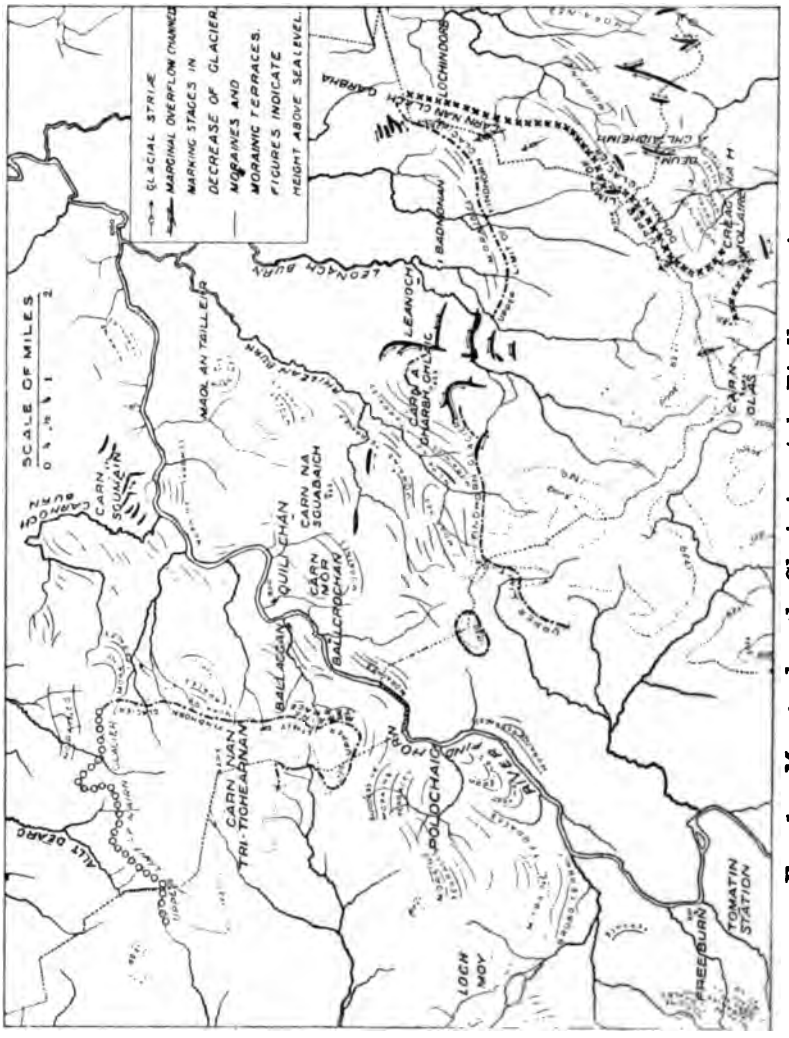

FIG. 1.—*Map to show the Glaciation of the Findhorn region.*

In the ground on both sides of the Findhorn east of the county boundary between Inverness and Nairn, proofs of the retreat of the Findhorn glacier are very conspicuous. On the plateau south Dr. Peach

. Peach. of Quilichan and Ballcrochan, there is a succession of moraines arranged approximately east and west, extending up to the 1,750 feet level, while Carn Sguabach and Carn Mor are seen to be fringed with moraine terraces. North of the Findhorn gorge the upper limit of the ice is very well defined especially at the sources of the Ballagan Burn. There, at a height of about 1,750 feet, there is a broad platform of sand and gravel resting on Boulder-clay deeply trenched by the separate branches of the stream. The platform is part of a terrace running along the hillside which passes out laterally into moraines. Below this level the hill is terraced with a succession of moraines, many of which are water dressed.

In the gorge of the Findhorn from Quilichan up to the county boundary, there are striking proofs of the retreat of the glacier. The moraines on the plateau, when traced to the gorge are found to merge into terraces which border it on either side; indeed it is difficult to discriminate between the lower moraine terraces and the higher of the true river terraces. It can be demonstrated that many of the terraces, where tributaries join the main valley, are ordinary alluvial deltas brought down by the side streams and heaped up against the edge of the glacier that still partly filled the gorge, for true terminal moraines can be seen at lower levels and close up to the steep margins of these terraces.

'. Hinx- n. In the streams which flow into the Findhorn, between Polochaig and Tomatin from the east, the boulder clay is capped by more gravelly and morainic material. A group of moraines fills a hollow on the hill slope, about a mile south of Polochaig. They form a series of well defined steep-sided ridges, rising one behind the other to within a short distance of the watershed, and evidently mark the successive levels of the glacier, which, dammed back by the constriction of the valley in the Polochaig gorge, was here embayed. The lowest level of these moraines appears to merge into the high-level terrace-alluvia of the river.

. Horne. West of Freeburn the most notable moraine occurs on the hill slope about two miles, N.W., of Freeburn where an isolated ridge, with occasional boulders on its surface and resting on a platform of boulder clay, is traceable for a mile. The morainic gravels have usually terrace-shaped outlines which are conspicuously seen on the hill slopes north-west of Tomatin Station and west of Moy.

'. Ander- l. On the south side of the watershed between the Findhorn and the Dulnan near Carn Glas (2,162 feet) and Creag na h-Iolaire (1,750 feet) the rock surfaces are well glaciated. The striae indicate a movement of the ice in a northerly direction, parallel to the course of the River Spey, and thick enough to override all the hills in the district. There is evidence also of a later, and probably of an earlier period of glaciation, when the ice was deflected by the watershed above referred to, and moved in a north-easterly direction parallel to the watershed itself.

This conclusion is borne out by the numerous morainic features which traverse the country, parallel to the contour lines, and extend in some places close up to the watershed. There are also two very marked dry valleys, crossing the ridge of Creag na h-Iolaire in an easterly and north-easterly direction. It is difficult to account for the preservation of the northerly striae which run obliquely across the direction of these valleys, except on the supposition that the glaciation which gave rise to the dry valleys was of an earlier date. Mr. Anderson.

III. West Midlothian and Peebles District.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. L. W. Hinxman, B.A.
Mr. J. S. Grant Wilson. } Geologists.
Mr. C. B. Crampton, M.B., C.M.

LOWER OLD RED SANDSTONE.

During the spring some slight modifications were made in the mapping of the volcanic rocks of Lower Old Red Sandstone age in the Pentland Hills. With the co-operation of Dr. Flett, who visited several of the chief exposures of these rocks in Sheet 32 with Dr. Peach, further collections of specimens for microscopical examination were made. Dr. Flett has thus been able to show that the series of volcanic rocks of Lower Old Red Sandstone age in that region range from basalts to rhyolites. Dr. Peach.

UPPER OLD RED SANDSTONE.

Owing to the absence of fossils, it has hitherto been difficult to define the upper limit of this formation in Midlothian. During the early part of last season, by following up a clue detected by Dr. Peach while revising the geology of Arthur's Seat, fish remains were obtained by the Survey Collectors from the sandstones beneath the dolerite sill of Salisbury Crags. These were submitted to Dr. Traquair who identified, among them, teeth and scales of *Holoptychius nobilissimus* characteristic of the Upper Old Red Sandstone. Thereafter the Craigmillar sandstones, to the south of Arthur's seat, were carefully searched and yielded some fragmentary fish remains, pronounced by Dr. Traquair to belong also to *Holoptychius nobilissimus*. Encouraged by these discoveries Mr. Tait next examined the conglomeratic red sandstone, associated with cornstone, that underlie the cementstone beds of Ballagan type near the Torduff and Clubbiedean reservoirs, where fish remains of a less definite character were obtained, (see appendix). The sandstones and breccias at these localities are now grouped with the Upper Old Red Sandstone, and the line for the upper limit of this formation has been drawn at the point where the Ballagan type of the Cementstone group (Carboniferous) first appears.

CARBONIFEROUS.

Calciferous Sandstone Series.

r. Peach. Cementstones and shales of Ballagan type, and sandstones, overlie the dolerite sill of Salisbury Crags, and are exposed in quarries on the Hunter's Bog where they have yielded *Estheria peachi*. During last season, Carboniferous plants were obtained from dark coaly seams associated with yellow sandstones and grey shales and fireclay, exposed in a railway siding at Raeburn's Brewery at Duddingston, where they immediately overlie the Craigmillar sandstones. In accordance with the evidence just described the base line of the Carboniferous system has been drawn throughout the area embraced in Sheet 32 one-inch.

During the revision of that part of the Midlothian coal-field lying to the east of the Pentlands and near the southern edge of Sheet 32, outcrops of oil shale were observed in the North Esk, a little below Carlops, which dip at high angles to the S. E. A series of measurements taken from the outcrop of what is considered to be the representative of the Gilmerton Limestone, and the fossils collected from the different beds exposed in the Esk and neighbouring stream sections, seem to point to the conclusion that two of these bands of oil shale correspond in position to those of the Broxburn and Pentland shales extensively wrought further to the N. W., at Straiton. This furnishes strong evidence in favour of the opinion that the Straiton Oil Shale field extends to the south west, at least as far as Carlops.

The occurrence of a basic lava flow on the horizon of the Burdiehouse limestone, which is traceable from near the edge of Sheet 32 to about a mile south of Carlops, is a new feature in the geology of Midlothian. A marine zone containing lamellibranchs chiefly, but with such clear water forms as encrinites, *Productus* and *Spirifer*, is met with about 150 feet below the outcrop of the Burdiehouse limestone in the North Esk section.

IV. East Midlothian and Haddington District.

Mr. C. T. Clough, M. A., District Geologist.

Mr. C. B. Crampton, M.B., C.M.
Mr. H. B. Muff, B.A.,
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.
} Geologists.

UPPER OLD RED SANDSTONE.

r. Muff. *Dunbar to East Linton.*—In the small bay below the western outskirts of Dunbar massive speckled sandstones pass upwards into cornstones and are overlaid by cementstone beds of the Calciferous Sandstone Series. As the sequence resembles that seen on the coast near Cockburnspath, where the passage upwards from the

Upper Old Red Sandstone to the Carboniferous is exposed, and as the speckled sandstones of the Dunbar section are identical in character with those at Stenton, which have always been considered to be of Old Red Sandstone age, the cornstones and associated strata at Dunbar have been grouped with the upper division of that formation. Mr. Muff.

CARBONIFEROUS.

Calciferous Sandstone Series, and Associated Volcanic Rocks.

Dunbar to East Linton.—On the coast between Dunbar and the mouth of the Tyne, about twenty volcanic necks are exposed in section, some of which have been described by Sir Archibald Geikie, who called attention to the impossibility of accounting for the patches of ash by any system of faulting.* The surrounding strata, consisting of Old Red Sandstone or Carboniferous rocks of the Cementstone group, lie at gentle angles, and may, in many cases, be followed completely round the vent. As each bed approaches the orifice, it bends over sharply and dips down at a high angle towards the neck: in some cases, however, the beds are merely truncated.

The materials filling the necks consist chiefly of ash, often bedded and containing abundant quartz-grains, blocks of Carboniferous and Old Red Sandstone rocks, together with bombs and irregular lumps of slaggy basaltic lava. Intrusions of basalt sometimes pierce the tuff. In the case of some of the smaller orifices the material consists of coarse breccia composed solely of fragments of local rocks. Such vents are interesting as they pierce the summits of low anticlines in the Carboniferous strata, which are overlapped by the succeeding beds, thus proving that the folds are of the same age. In one case, part of the orifice is buried under cementstones and shales, thus proving that some of the smaller vents are contemporaneous with the lower division of the Calciferous Sandstone Series.

The large area of red tuff east of Dunbar evidently fills a large vent, for the Carboniferous strata, on approaching the western edge of the mass, dip down at high angles towards the ash, and upwards of 50 feet of beds are truncated by the tuff along the western margin of the orifice. The boundary line along its eastern margin was formerly mapped as a fault, but it may, more probably, be the edge of the volcanic pipe, as the ash passes across this line and fills up cracks in the sedimentary rocks. This neck and the others that pierce the Old Red Sandstone and Cementstone strata are older than the east and west dolerite dykes which traverse them. With the exception of some of the smaller vents, they are probably of the age of the volcanic rocks of the Garlton Hills, which belong to the higher parts of the Calciferous Sandstone Series.

* "The Geology of East Lothian." *Geol. Survey Memoir* 1866, pp. 43–45.

r. Muff. A very good section of the volcanic rocks that form part of the Garlton Hills plateau is exposed in the railway cutting on the east side of East Linton Station. At the base are two beds of limestone, associated with fine red tuff and surmounted by seven or more lava-flows dipping towards the west. The upper flows are olivine basalts, whilst the lower are less basic in composition and may be andesites. The top and bottom of each flow are very vesicular, hence it is sometimes difficult to determine the junction line, which, of course, is an uneven one. In one place a bed of ashy bole, about one foot thick, separates the flows.

r. Bailey. *Garvald and Traprain Law.*—The following is the descending order of succession in this area :—

(*e*) Trachytic ash.
(*d*) Trachytic lavas.
(*c*) Basic lavas.
(*b*) Basic Ash with Sunnyside Limestone.
(*a*) Sedimentary beds of the Cementstone Group.

This sequence, except as regards the position of division (*e*), has long been known to exist in the district north of Traprain Law, and has now been proved to extend over the country south of that eminence, with a more regular development than hitherto supposed. The field work during the past season has shown that every group of the Garlton Hill volcanic series continues without a break round the western end of Traprain Law into the ground south of that hill. The connecting link is narrow, for, as shown on the old edition of the Geological Survey map, the base of the volcanic series at this point makes a sudden deflection of two and a half miles to the west, thus making a circuit of Traprain Law, where the outcrop of the group is greatly constricted. There can be no doubt that this deflection is due to the igneous intrusion of that hill, which will be referred to in the sequel.

Evidence has been obtained in support of the old view that the volcanic series thins away rapidly to the south. This attenuation is best shown on the south side of the great north-east and south-west fault, which, from Dunbar to a point west of Garvald, has brought Carboniferous strata against Upper Old Red Sandstone rocks. In last year's Summary of Progress, p. 100, evidence was adduced pointing to the conclusion that this dislocation extends further west than previously supposed. Confirmation of this view has now been obtained, for both the basaltic lavas and a member of the trachyte group have been found on its southern or upthrow side. The lavas, however, are there gradually separated from one another by intercalations of sandstone, and die out completely before reaching Gifford Water; the only representative of the volcanic rocks which reaches this stream being a basic tuff. The association of the basic ash with the lavas on the south side of the fault referred to, confirms the view that this tuff may represent approximately the position of the basement ash of the Garlton Hill volcanic series.

North-east of Traprain Law, the lavas of group (*c*) consist of a marked alternation of more or less basic rocks; to the south, it is represented only by three lavas, comprising an upper basalt, underlain by two flows of hornblende-andesite, a petrographical type not yet described from the district. Mr. Baile

In the trachytic lavas (*d*), and trachytic ashes (*e*), types with conspicuous porphyritic felspars are not found in the country south of Traprain. A little west of Whitelaw a basaltic flow appears some distance up in the trachytic division, but such a recurrence of basalt is not known elsewhere.

Edge Coal Group.

Tranent and Elphingstone.—Though a good deal of new information has been obtained, not much progress has been made in tracing the outcrops of the coals of this district, which is largely due to the flatness of the strata and the gently undulating character of the surface. Parts of the outcrop of the Great Seam, and, in one place, of the Splint Coal, have been more accurately defined than in the former map. Mr. Andeson.

No coal corresponding to the Hauchielin, or lower Parrot seam occurs in this area. In this eastern part of the district, however, near Macmerry, two coals are found a short distance apart, low down in the Edge Coal Series, which are known respectively as the Splint Coal and the Under Coal. They represent the Splint and Rough Coals of the district further south, and the Kailblades seams of Arniston and Newbattle. They have been met with in a bore put down at Fleets Pit, a quarter of a mile N.E. from North Elphingstone, and it is probable that one or other of these coals corresponds to the Diamond No. 1 of Prestongrange and Dolphingston Collieries. The next in ascending order is known in the Macmerry district as the Panwood Coal, which Dr. Crampton has shown to be the same as that known elsewhere as the Five-Feet seam. In other parts of this district, it has certain well marked characteristics which enable it to be identified with the Jewel Coal of Preston Links, Northfield, Prestongrange and Dolphingston Collieries. A band of ironstone used to be worked near Macmerry under the name of the Penstone-ironstone, which occurs a short distance above the Panwood Coal. In the now disused colliery of Dolphingston, situated just within the eastern limit of Sheet 32, an ironstone was wrought a short distance above the Jewel Coal, and this affords interesting confirmatory evidence that the two coals are the same.

Above the horizon of the Five-Feet seam there is usually about 100 feet of barren strata followed in order by the same sequence of coals as that described by Dr. Crampton in the southern part of the basin. By means of comparative sections of the strata the conclusion has been reached that the Jewel Coal of Wallyford and Carberry Collieries may correspond to the Three-Feet Coal of the East Lothian basin, though it must be understood that

. Ander- the evidence is by no means conclusive. On this supposition
l. the underlying Four-Feet seam might be the same as the Parrot Rough at Wallyford, while it would be necessary to suppose that the overlying Parrot and Splint Coals disappear when followed westwards to that colliery.

No faults of considerable magnitude have been added to the list of those previously known; just north of Elphingstone village, the strata are thrown into a curious trough-shaped depression by two faults running east and west, each of which has a downthrow of about 80 feet.

. Cramp- *Area South of Ormiston.*—There are few natural sections, and
l. the fresh information has been obtained chiefly from the pits now working, or from the journals of bores and old plans. The outcrops of some of the coals have been altered, and various new lines of crop have been added, chiefly from information obtained from bores.

The following is a generalised section of the coals and intervening strata in this area :—

Great Seam.
Strata about 26 fms.
Tranent Splint.
Strata about 1 or 2 fms.
Parrot Rough.
Strata about 2 fms.
Three-Feet coal.
Strata about 3 or 4 fms.
Four-Feet coal.
Strata about 10 or 15 fms.
Five-Feet coal, Panwood Coal and Ironstone position.
Strata about 10 fms.
Rough Coal.
Strata about 2 fms.
Splint Coal.
Strata about 12 fms.
} Position of *Kailblades* of Arniston.
Hauchelin or *Parrot Coal.*

The main point of interest in the above section lies in the correlation of the coal seams with those of neighbouring areas. It has long been known that the Splint and Rough coals lie on the same horizon as the Kailblades of Arniston, and it is now evident that the Panwood Coal and Ironstone are on the horizon of the Five-Feet Coal of Elphingstone and Tranent, and not below it, as was formerly supposed.

The Great Seam lies in a small basin between the Tyne Water and Woodhall, and has been proved by bores in the neighbourhood of Red Row. Pits are now being sunk to reach it, and are expected soon to be in operation. This basin is bounded on the north-east by a fault with a downthrow to the south-west of about 30 fathoms, which, in the previous edition of the Geological Survey map, was shown to fault the lower coals in the Huntlaw Collieries.

It is probable that a small basin, lying between Fordel and Oxenford Mains, includes beds as high as the Splint and Parrot Rough

Coals; but it is uncertain whether these higher beds owe their position to faulting or not.

Upper Limestone Group.

Tranent and Elphingstone.—Evidence has been obtained of the existence of two thin bands of limestone, some distance above the Great Seam, in the centre of the basin. One of these, known familiarly as "Wattie's Toe," and occurring from five to ten fathoms above the Great Seam,* may be the Index limestone. The other appears at a higher level, probably about thirty fathoms above the Great Seam, in the shaft of Fleets pit, about a quarter of a mile N.E. of North Elphingstone, but the horizon of this limestone is uncertain. Mr. Anderson.

Laccolites, Intrusive Sheets and Dykes.

Dunbar to East Linton.—The dolerite dykes having an E. and W. or E.N.E. and W.S.W. trend, are intruded into the tuff filling the volcanic necks of this area. In some cases, where the vents lie in the track of a dyke, the dolerite traverses the ash or breccia in veins, but does not pierce it completely; on the other hand, fragments of the dyke rocks have not been found either in the ash or in the breccia filling the vents. It is, therefore, evident that the east and west dykes are later than these necks. Mr. Muff.

Garvald and Traprain Law.—Some new evidence has been obtained regarding the field relations of the phonolitic trachyte of Traprain Law, the petrographical characters of which have been described by Dr. Hatch in his paper on "The Lower Carboniferous Volcanic Rocks of East Lothian."† Mr. Bailey.

The trachyte of that dome-shaped eminence is separated by a narrow belt of sediment from another trachyte intrusion on the north, which, in the old map, was shown as if continuous with that of Traprain Law. This northerly intrusion will, in the sequel, be referred to as the Hairy Craig sill, from a local name not given on the one-inch map.

Mr. Howell's mapping established the fact that the Traprain Law intrusion tilted up the surrounding strata, which has been confirmed by recent exposures, showing that the high dip of the beds is found on every side. There is evidence, also, that the upturned strata formerly spread continuously over that hill, and have probably only recently been removed by denudation. Thus, on the western front, which bore the full force of glacial erosion, igneous rock is exposed from the base to the top, and the sedimentary strata seen near the foot have a dip of about 80°. But at the sheltered eastern extremity, the sediments creep half way up the hill, and sandstones are exposed in this position with a dip of only 50°. Moreover, the rounded outline

* This information has been kindly supplied by Mr. Henderson, Mineral Boring Contractor, Edinburgh.

† *Trans. Roy. Soc. Edin.* vol. xxxvii. p. 124.

Mr. Bailey. of the law has been determined by a system of joint-planes arching over the top * and sweeping round either end, probably developed during the gradual cooling of the mass and in directions parallel to the original surface of the intrusion. This platy jointing is not due to fluxional movement of the magma, for a well-developed flow structure is also exhibited, the convolutions of which are repeatedly cut by the more even jointing; but, nevertheless, the two structures are, in general, parallel. The hypothesis that the jointing was developed during the cooling of the mass is supported by the following facts, that in the exposure of sediment close to the trachyte the bedding of the one agrees in inclination with the platy structure of the other, and that in the quarry, the laminæ, formed by the joints, are thin near the exterior, while, towards the centre of the mass they become gradually thicker, and the crystalline texture coarser. Assuming, then, that the platy jointing was developed during cooling, and parallel to the original surface of the rock, the fact that this structure arches over the hill strongly supports the view that the rock consolidated under a cover of tilted sediments. As an argument against the theory that the rock is part of the pipe of an old volcano, it may be mentioned that the amount of alteration induced in the surrounding strata is slight. Unfortunately there is very little evidence regarding the character of the base of the intrusion, though, at one place the deeply eroded western front shows a vertical blocky columnar jointing, which suggests a horizontal bottom. The evidence, then, though incomplete, favours the view that the intrusion is a laccolite of the type first described by Mr. G. K. Gilbert.†

It is evident that the uprise of the trachyte of Traprain Law belongs to a very late phase of the volcanic activity, as the intrusion has tilted the basic lavas and seems also to have deflected the strike of the trachytic flows, though none of the latter are preserved within the area of highly inclined rocks surrounding the mass.

The intrusive trachyte of Hairy Craig has also tilted the overlying strata of the Cementstone group, but, since its eastern boundary is a fault, the high angle of dip is confined to the western side of that dislocation. Although an eruptive mass, it frequently possesses a very slaggy upper surface, like that of a lava—a peculiarity which is perhaps due to its position on the flanks of the Traprain Law laccolite; for Gilbert has pointed out (*loc. cit.* p. 20, fig. 9) that the outer limit of flexure of the strata surrounding a laccolite marks a zone particularly prone to sill intrusion, no doubt due to relief of pressure in this position. The Hairy Craig sill may well have been intruded under diminished pressure, from the same reservoir and at the same time as the trachyte of Traprain Law.

* This feature is clearly shown in the large photograph reproduced by Sir A. Geikie, in his "*Ancient Volcanoes of Great Britain*," vol. 1, fig. 133, p. 404.

† *Report on the Geology of the Henry Mountains.* (U.S. Geogr. and Geol. Survey 1877).

A large sill of limburgite south of Linplum, near Gifford, shows intrusive junctions with the basement ash of the volcanic series. Three miles to the east, at Stenton, a similar limburgite is irregularly intruded into an agglomerate, which appears to be in a neck piercing the Upper Old Red Sandstone, and near Presmennan Loch there is a 2-feet dyke of limburgite. The limburgite from Chester's quarry * which occurs as a sheet in the Upper Old Red Sandstone is presumably intrusive, although its junctions are nowhere exposed. It appears, then, that in East Lothian typical limburgite must be considered as an intrusive rock. Mr. Bailey.

PLEISTOCENE AND RECENT.

Garvald and Traprain Law.—The eastern portion of the Lammermuir Hills furnishes many fine examples of the effects produced by marginal streams during the general retreat of the ice sheet. For an excellent description, reference may be made to the Geological Survey Memoir,† written long before special attention had been called to such phenomena.

ECONOMICS.

Garvald and Traprain Law.—The Chester's Quarry (limburgite) and the Traprain Law quarry (phonolitic trachyte), are both worked by the Haddingtonshire County Council for road metal, and the supply in each case is practically inexhaustible. The Old Red Sandstone furnishes building material for local purposes but, unfortunately, it is much broken by small faults and irregular joints. The Sunnyside Limestone is at present wrought near Whittinghame for road metal. As the district is without railway connection, it might be profitable also to burn this limestone.

The water supply of Haddington is obtained chiefly from springs issuing at the base of the sill in Chester's Quarry in the dry valley beside the quarry. The sandstones furnishing the supply are of Upper Old Red Sandstone age, and the dry valley is one of those eroded during the presence in its vicinity of the retreating ice front.

Tranent and Ormiston Area.—In the Tranent neighbourhood several quarries either have been or are now worked for building stone, on a horizon somewhat above the level of the Great Seam. To the west of Tranent two sandstones are quarried, separated by a few feet of arenaceous strata containing a thin coal. The lower one is coarse and gritty, and white in colour; the upper one is brown and contains numerous plant remains Dr. Crampton and Mr Anderson.

* Described by Dr. Hatch, *loc. cit.* p. 116. If Dr. Hatch's suggestion, that nepheline is present in the ground mass, be confirmed, the rock will have to be called nepheline basalt.

† J. Young, *Geology of East Lothian*, 1866, pp. 63–64.

In making the new railway to the pit at Preston Links, a bed of fine white fireclay at least two feet in thickness, has been discovered, whose position is probably in the higher part of the Upper Limestone series.

V.—Glasgow District.

B. N. Peach, LL.D., F.R.S., District Geologist.
L. W. Hinxman, B.A.,
C. B. Crampton, M.B., C.M.,
E. B. Bailey, B.A.,
R. G. Carruthers.
} Geologists.

UPPER OLD RED SANDSTONE.

Mr. Bailey. In the Strathblane area Mr. Bailey mapped certain soft purple and white sandstones and red marls with cornstone concretions, surmounted by a thick band of cornstone which belongs to the higher portion of this formation. Although no fish remans were obtained from these beds, Mr. Macconochie formerly collected scales of *Holoptychius nobilissimus* from strata on this horizon in adjoining ground towards the north-east.

CARBONIFEROUS.

Calciferous Sandstone Series.

The Calciferous Sandstone series as developed in the present area may be grouped in the following descending order :—

(*c*) Craigmaddie Muir Sandstone.
(*b*) Volcanic rocks of the Campsie and Kilpatrick Hills.
(*a*) Ballagan Beds.

Mr. Bailey. (*a*) *Ballagan Beds.*—Overlying the Upper Old Red Sandstone, just described, come the cement-stones and shales of Ballagan type, which pass conformably upwards into the volcanic series.

(*b*) *Volcanic Rocks of the Campsie Hills.*—During the recent revision the basalt lavas have been divided into a lower group which are non-porphyritic or only sparingly so, and an upper highly porphyritic group. The outcrop of one of the flows in the lower division—the third from the base in the Strathblane Valley—has been traced for four and a half miles, whereby the positions of several large faults, which break up the volcanic plateau into sections, has been defined in a more complete manner than formerly. The mass of igneous material which slopes down from the volcanic plateau to the bottom of the Blane Valley, west of Ballagan, instead of being intrusive as shown on the map, is really a part of the volcanic series, including several lava-flows, let down by a powerful fault.

Along the northern edge of the volcanic plateau between Strathblane and Fintry, a mass of coarse agglomerate flanked by intrusive basalt has been traced for a distance of four and a half

miles, which evidently fills an elongated vent not exceeding a quarter of a mile in width. Mr. Bailey associates the great length of this fissure-like vent with the widespread nature of the early flows which are conformable to the underlying sediments. The lower lava streams appear to thicken as the vent is approached and the higher flows slope away from it. The long axis of this fissure eruption which is approximately N.E. and S.W., coincides in direction with that of numerous dykes in the contiguous sediments which agree in petrological characters with the two types of lavas that make up this part of the plateau. Notwithstanding their great number no case of a dyke feeding a lava-flow has been observed. Mr. Bailey

(c) *Craigmaddie Muir Sandstone Group.*—The coarse sandstones and conglomerates from 500 to 600 feet in thickness which overlie the volcanic rocks of the Kilpatrick Hills have hitherto been classed with the Carboniferous Limestone series by the Geological Survey. But as they underlie the Hurlet Limestone which has been taken as the base of that series in the south part of the Lanarkshire coalfield and in the Bathgate district, it is evident that these sandstones must represent the upper portion of the Lothian Oil Shale Group of the Calciferous Sandstone series. It is therefore proposed during the present revision to consider the base of the Hurlet Limestone as the top of the Calciferous Sandstone series. Dr. Peach.

Taking the base of the Hurlet Limestone as the top of this group Dr. Crampton shows, by means of the following generalised vertical sections, the variation in this group as developed south of Campsie and in the Corrie Burn, about five miles further to the east:— Dr. Crampton.

S. Campsie Hill.

	Ft.	in.
Hurlet limestone	–	
Black alum shale	2	14
Hurlet coal (pyritous)	3	6
Fireclay	–	
Hard entomostracan limestone	4	8
Shale		
Limestone with marine fossils	–	
Ganisters, fireclays, and thin coals	–	
White sandstone	–	
Thin hard limestone	–	
Craigmaddie Muir Sandstones, and conglomerates	400–500	0
Volcanic rocks of Kilpatrick Hills	–	

Corrie Burn.

	Ft.	in.
Hurlet limestone	–	
Black alum shale	0	14
Coal and ironstone	1	8
White marl	4	0
Coral limestone	8	0
Black shale and ironstone	12	0
Ash and marl	20	0
Sandstone	3	8
Black shale	20	0
Traps and ashes with occasional sedimentary bands	–	
Volcanic rocks of Campsie Hills	–	

Further modifications of the higher beds on the south hill of Campsie appear when the beds are traced westwards. The alum shale, formerly extensively wrought at Campsie, is only one inch thick in the New Kilpatrick district; the entomostracan limestone has only a thin representative at Baljaffray and is absent at Duntocher. Mr. Carruthers.

Carboniferous Limestone Series.

Peach. The Carboniferous Limestone series, with the Hurlet Limestone as its base, can be conveniently subdivided into the usual three groups, in the present area, viz. :—

(*c*) An upper group of three or more limestones separated by sandstones, shales, and fireclays, with a few beds of workable coal.

(*b*) A middle group, rich in workable coal and ironstone beds separated by sandstones and shales.

(*a*) A lower group of limestones, the intervening strata consisting chiefly of dark shales and clay ironstone bands with some sandstones near the top of the group.

Cramp- and Mr. uthers. (*a*) *Lower Group.*—In this district it has been noted that the Hurlet limestone varies in thickness from four feet in the south hill of Campsie to fifteen feet in the Corrie Burn near Kilsyth. An oil shale associated with one of the Hosies limestones, which was extensively worked at Johnstone south of Glasgow, is traceable throughout part of this area. Further, the topmost limestone of the group is richly charged with different species of Bellerophon—a feature which differentiates it from the lower calcareous bands.

Hinx- (*b*) *Middle Group.*—Only one of the black band ironstones of this group, viz., the Possil Main seam, is now being wrought in the Cadder and Summerston district, north-east of Glasgow, by the Carron Iron Company and the Summerlee Iron and Steel Company. Owing to the kindness of the managers, a considerable amount of new information has been added to the maps in this part of the field. This rich band probably represents the seam which, in the present map, is shown as the "Upper Possil Ironstone."

Carruth- From information kindly supplied by Messrs. Addie & Son, Mr. Carruthers has been able to plot an accurate vertical section at Garscube from the Cowglen or Index Limestone, through the Possil and underlying ironstones. On comparing this section with those in the adjoining districts of Knightswood and Garscaddan it appears that the important group of ironstones lying between the Gas Coal (the lowest of the Possil seams) and the Garibaldi Clayband Ironstones, retain their thickness and position over the whole area. Hence there has been no difficulty in correlating the "Brown Stone" of Knightswood and Garscube with the "Banton Blackband Ironstone"—a widely distributed and well-known seam. The Possil Coals lying above the Gas Coal are, on the other hand, local in character and it has been found difficult to correlate the the individual seams with coals and ironstones occupying the same general position in the Cadder field, a few miles to the north-west.

Peach. (*c*) *Upper Group.*—In those portions of Sheets 30 and 31 which fall within the present district, the Robroyston Limestone, the local name for the Calmy or Arden Limestone (No. 5 of Midlothian) has been mapped as the highest bed of the Carboniferous Limestone series, while, in the central region of Sheet 31, and everywhere in the eastern part of that map, the top of the Levenseat or Castle-

cary Limestone (No. 6 Midlothian) is used as the division line between the Carboniferous Limestone series and Millstone Grit. That a representative of the Castlecary Limestone occurs within the present district has been proved by evidence from bores and railway cuttings, and the boundary line has therefore been altered. The identification of the Castlecary Limestone in this district is of economic importance, as it immediately underlies the valuable fireclays in the Millstone Grit that are extensively worked in the Garnkirk and Castlecary regions to the east. Dr. Peach

From six to eight limestones of the upper group have been recognised in different parts of this region, chiefly in bores and shaft sections, there being very few natural sections of the strata in the district. The lowest band, the Rough, Cowglen, or Index, is well seen in the North British Railway cutting, one-third mile S.W. of Bishopbriggs Station, where it is a hard compact dolomitic limestone, 4 feet thick, with a rough concretionary surface, rusty weathering and containing few or no fossils. Analysis of this rock shows that it is a dolomite in which the magnesia has been partly replaced by iron. Intercalated with the thick Bishopbriggs Sandstone which overlies the Cowglen Limestone, in the same cutting, is a locally developed thin cement-stone with marine fossils; and two other cement-stone bands occur immediately above that sandstone in the Huntershill Quarries at Bishopbriggs. Mr. Hinxman.

The evidence from bores in different parts of the area further shows that from two to four thin limestone bands may be present at varying distances between the Garnkirk (Calmy) and Cowglen (Index) Limestones.

The Calmy, Garnkirk, or Robroyston Limestone—an impure argillaceous limestone—is nowhere well exposed in the district, but has been proved in most of the bores of the Cadder and Blackhill mineral fields. Its horizon is very constant in character, the calcareous rock occurring in two or sometimes three bands with shale partings. These are invariably followed below by eight to ten feet of shales with ironstone ribs, beneath which lies the Hirst Coal.

The actual or approximate position of the Castlecary Limestone has already been determined in several localities, and further investigation in the Garnkirk district will, it is hoped, enable a base line to be drawn for the Millstone Grit, that shall not be inconsistent with the mapping in the ground to the east.

Information derived from journals of bores, shaft sections, and plans of workings, kindly placed at the disposal of the Survey by the Carron Iron Company and the Summerlee Iron and Steel Company, have enabled Mr. Hinxman to indicate the approximate positions of the Upper Limestones and Main Ironstone on the Cadder, Blackhill, and Summerston mineral fields. The evidence thus obtained shows that the structure of this region is somewhat complex, the strata having been thrown into a series of domes and shallow basins which have further been truncated by a system

r. Hinxan. of more or less parallel faults. Evidence derived from bores put down in the Balmore Haughs, north of the Kelvin, shows that the centre of one of the basins, to the west of Balmore is occupied by the Millstone Grit.

Buried River Channel of the Kelvin Valley.

r. Hinxan and Mr. arruthers. An eastward extension of this pre-glacial channel, shown on Sheet 30 between Kilbowie and the River Kelvin, is indicated by the bores put down near Summerton and the Balmore Haughs. Additional information regarding the course and depth of this channel was also obtained in the district of Bearsden and Dalmuir which, together with the evidence formerly available, has enabled Mr. Carruthers to plot a section on the six-inch scale with a reasonable amount of accuracy.

GLACIATION AND GLACIAL DEPOSITS.

r. Peach. Two sets of striæ have been observed within the City of Glasgow and the surrounding district; the older indicating generally a movement towards the south, and the later, towards the east. As will be shown in the sequel, there is evidence of two boulder-clays in the district, so that the striæ may belong to two different periods of glaciation corresponding to these ground-moraines.

r. Hinxan. The country eastwards from Cadder and Bishopbriggs and south of Kirkintilloch is thickly covered with a stiff stony grey or yellowish boulder-clay, disposed in long smooth-topped ridges. Between these lie winding flats of alluvial or peaty soil, marking the site of former shallow lochans which occupied hollows in the glacial deposit.

The long axes of these boulder-clay "drumlins" run a little N. of E. and S. of W., indicating the direction of the ice-movement by which they were produced. On the ridge that extends westwards from Cadder between the Kelvin Valley and the Forth and Clyde Canal, there is evidence, mostly derived from bores, of an upper boulder-clay, reddish in colour, and separated from the lower grey boulder-clay by a variable thickness of sand and gravel. That this intermediate deposit may be lenticular and of local occurrence is inferred from the apparently continuous section of boulder-clay afforded by the mineral railway that descends the hill slope to the west of Mavis Valley.

r. Carruthrs. Good evidence of the occurrence of two boulder-clays has been obtained during the excavation of a large dock at Yoker. During the recent revision the sections had been covered up, but the facts were ascertained through the kindness of Mr. MacNair, of the Glasgow Corporation Museum, Mr. Somerville, and Mr. Stevenson, the assistant engineer, when the excavation was in progress. The upper clay was dark red in colour and consisted largely of boulders derived from the areas of crystalline schists and volcanic rocks to the north-west. It was separated by a thin layer of sand from the lower till, which, as seen at present in the new railway cutting

close at hand, is a dark blue clay full of fragments of the local shales and ironstones, a few blocks of limestone, together with some foreign boulders. It is worth noting that both clays contain fragments of the Garabal Hill granite from the head of Loch Fyne. Mr. Carruthers.

A remarkable deposit of laminated false-bedded sand and silt, with intercalated beds of coarser material along the landward margin, has been mapped along the south side of the Kelvin Valley between Kirkintilloch and Cadder. Where undenuded, it forms a wide flat-topped terrace with a mean elevation of 170 feet, whose steeply scarped front rises above the alluvial flat of the River Kelvin, opposite Torrance, in cliffs of sand 40 to 60 feet in height. It is probable that these sands and gravels were laid down during late glacial times in a lake which occupied the upper part of the Kelvin Valley, and whose waters, dammed back by ice coming from the west, may have escaped eastwards over the present watershed of the Kelvin. Mr. Hinxman.

ECONOMICS.

Iron Ore.

The most important economic product of this district at the present time is the Blackband Ironstone, which is now being extensively wrought by the Carron Company in their pits at Cadder and by the Summerlee Steel and Iron Company at Blackhill near Summerston. These are almost the only localities where ironstone is now raised in Scotland, except as a by-product. The seam worked in both fields is the Main Possil Ironstone, which, in the Cadder field lies 46 fathoms below the Cowglen or Index Limestone, and 15 fathoms above the Main Possil Coal; and at Blackhill is 55 fathoms below that limestone. Mr. Hinxman.

The coal which occurs along with the ironstone is used to calcine the latter at the pits; the "char" or resultant magnetic oxide being conveyed to Carron and Coatbridge for smelting.

Building Stone.

The Bishopbriggs Sandstone, which lies a short distance above the Cowglen or Index Limestone, affords an excellent freestone which has long been extensively wrought at Bishopbriggs and is now being mined at the Huntershill Quarry. The rock affords a fine to medium grained white freestone in which the percentage of silica is as high as 91·50; while that of alumina is 4, and of lime 1. A lower sandstone, beneath the Cowglen Limestone, has also been quarried for building stone at Lambs Hill.

Paving Stone and Road Metal.

An east and west dolerite dyke is quarried at Claddens, one and a quarter miles east-north-east of Bishopbriggs. The rock is hard and compact, and generally free from veins and cavities. It is wrought for paving setts and cubes, and the refuse used for road metal.

Brick Works.

Mr. Hinxman. At the Bishopbriggs Brick Work two classes of brick are produced: one being made from ground-up shale refuse from the adjacent abandoned iron workings, with a small admixture of sandy clay. A brick of better appearance and colour, and more like a clay brick, is made from a clayey, blue shale, which is quarried at the surface beneath the Boulder Clay.

The Summerlee Iron Company also grind up the shale refuse at their Blackhill Pit for brick making. The bricks produced are hard and durable, but of bad colour, owing to the amount of iron in the shales. They are used chiefly for inside partition work.

VI. Bo'ness (Borrowstounness), Linlithgow, and Bathgate District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. J. S. G. Wilson.
Mr. H. B. Muff, B.A.
Mr. E. B. Bailey, B.A.
Mr. G. W. Grabham, B.A. } Geologists.

Mr. Clough. The area extending from Bo'ness by Linlithgow and Bathgate to Cobinshaw, revised during last season, embraces strata belonging mainly to the Carboniferous Limestone Series, which is here divisible into three groups as in the rest of Scotland. The remarkable feature of this region is the great development of igneous rocks, chiefly contemporaneous, which appear in the three divisions of the Carboniferous Limestone Series and in the higher portion of the underlying Calciferous Sandstone. The general dip of the strata is westerly at angles varying from 9° to 30°, so that the outcrop of each rock group runs approximately north and south.

In 1892, a revised edition of the one-inch map 32, showing the oilshale fields, was issued, and about the same time Mr. H. M. Cadell re-examined part of the ground along the eastern margin of Sheet 31. Since that date he has published a valuable account of the coalfields* with a geological map of this and the surrounding district.

Mr. Falconer has lately mapped, with special reference to the igneous rocks, a considerable part of the district under consideration, but his conclusions were not made public until the end of November† when nearly all the revision was completed by the Geological Survey.

Cordial thanks are due to many managers of mines, engineers, mineral borers, and especially to our former colleague Mr. Cadell,

* "The Carboniferous Limestone Coalfields of West Lothian," *Trans. Inst. Mining Engineers*, 1901.

† "The Igneous Geology of the Bathgate and Linlithgow Hills." *Trans. Roy. Soc. Edin.*, vol. xli.

for valuable information and assistance in the prosecution of the work.

CARBONIFEROUS.

Calciferous Sandstone Series.

Addiewell.—Between Addiewell Bridge and the east margin of the one-inch Sheet 31, there is a small area of the Calciferous Sandstone Series, traversed by the Breich Water, where Mr. Tait detected an estuarine limestone, 1 foot thick, of the Burdiehouse type and full of entomostraca. This bed, which lies 120 feet below the Cobinshaw Limestone, which is here regarded as the base of the Carboniferous Limestone Series, may be important for purposes of correlation. Mr. Wils

Carboniferous Limestone Series.

Lower Limestone Group.

Bo'ness to Linlithgow.—Four limestones are seen, on or near the coast, between Carriden Church and Blackness; the highest of which, the Carriden Limestone, forms the top of the lower limestone group. This bed, together with the two next in order below, also seen near the same locality, may be termed the Upper, Middle, and Lower Carriden Limestones. Mr. Clou

In a bore which has been made on the foreshore near No. 9 pit, Bridgeness, the Upper Carriden Limestone was found about 15 fathoms below the Smithy coal—usually the lowest workable seam in the Bo'ness Coalfield—where its thickness was about 4 feet, though, in the sandstone quarry near Carriden shore, it measures about 2 feet. It weathers with a yellow colour, and contains fragments of crinoids. The middle band, which is also crinoidal, and about 2 feet thick, is exposed in Carriden Glen above the volcanic ash, but its occurrence in the bore referred to is uncertain. It is separated from the Upper Carriden Limestone by flaggy yellow sandstone probably about 50 feet thick. Part of the Lower Carriden Limestone, which is very impure, is seen on the shore a few feet below the base of the Carriden tuff, where it is overlaid by a six-inch coal, not now visible, and has a similar thin seam below. The top of the limestone is not seen, but there cannot be more than 3 or 4 feet of shale separating the basal bed from the upper coal.

From the boring near No. 9 Pit, Bridgeness, and others, it is clear that, at a depth of about 200 feet below the Smithy Coal seam, there is an horizon—sometimes more than 60 feet thick, which contains various thin bands of limestone mixed with shale, fireclay, etc. It is probable that the Carriden Lower Limestone forms the top of this calcareous horizon, and that there are other limestones on the shore, a little way below it.

The lowest visible limestone is met with on the foreshore east of Blackness Bay, where the exposure is small and obscured [redacted]

r. Clough. the mud of the Forth. This band, which may be termed the Blackness Limestone, is compact, cream coloured, with pink blotches and about 2 feet thick. It dips to the N.E. but west of the exposure it must roll over to the N.W. to pass underneath the Carriden Limestones. It may be of fresh water origin and may belong to the Calciferous Sandstone Series.

Important evidence has been obtained from bores sunk near Springfield and Burghmuir, on the east side of Linlithgow Loch, which have pierced limestones that must be considerably below the position of the Smithy seam of the Bo'ness Coalfield. In the former, three or four impure limestones were found tolerably near together, belonging probably to the calcareous horizon of which the Carriden Lower Limestone is considered to be the top. The limestone in the Burghmuir bore lies more than 300 feet below the rock surface, and as no higher good limestone was pierced, it is probably more than 300 feet below the calcareous group just referred to in the Springfield bore.

r. Grab-ım. *Linlithgow to Cocklerue.*—In this area there are four important limestones, viz. :—those of Riccarton, Whitebaulks, Hillhouse and the Hospital, of which the first is the lowest. The Riccarton bed is from 10 to 12 feet thick, and is underlain by 8 feet of shale, but there can be no coal below for at least 20 feet. The Whitebaulks limestone is seen also at Carsie Hill (a quarter of a mile east of Cauldhame), where it is overlain by cherts.

The Hillhouse Limestone has been extensively worked in former years in quarries south of Hiltly, but the outcrop to the north is obscured by Drift. A bore put down at the St. Magdalene's Distillery passes through two limestones, the upper of which seems to correspond with that exposed during the construction of the Hospital, while the lower and thicker bed may represent the Hillhouse limestone.

r. Bailey. *Bathgate and Blackburn.*—Intercalated among the lava-flows of the Bathgate Hills, we find three limestones, which are given below in descending order :—

	Ft.
Petershill Limestone, maximum thickness - - - -	40
West Kirkton „ „ „ - - - -	10
East „ „ „ „ - - - -	10

All three limestones are fossiliferous, the upper two being marine while the East Kirkton Bed contains entomostraca and *Eurypterus Scouleri.** At Wardlaw, a little to the north of the area under description, there is another marine limestone intercalated in the volcanic series, which, as has long been known, occurs at a higher horizon than the Petershill bed.

Both the Petershill and the West Kirkton Limestones have each been correlated with the limestone known as the Hurlet, at Cobinshaw, Addiewell, and Blackburn, which may be referred to as the

Mem. Pal. Soc. Merostomata. H. Woodward, p. 132. Pl. XXV–XXVII.

Cobinshaw Hurlet. But it is impossible yet to feel confidence in either of these correlations. Mr. Baile

A bore put down at Mosside Colliery, half way between Bathgate and Blackburn, has pierced two limestones in the upper part of the Lower Limestone Group. In the Almond section, between Mosside Colliery and Skolie Burn, the approximate position of these two limestones is known, and below them two important marine limestones are exposed. The lower of these two is undoubtedly the Cobinshaw Hurlet, and is separated from the higher by about 300 feet of strata.

Foulshiels and Woodmuir Area.—The best exposure of the lowest limestone is at Cobinshaw, where the following section is visible :— Mr. Wilso

	Ft.	In.
Roof, shale	–	7
Limestone	5	6
Shale with 6-inch ironstone band	3	–
Coal	3	9
Holing, fireclay		

The limestone is a dark grey encrinital band and very fossiliferous. The coal is of an inferior quality with a low heating power, but is mined together with the limestone and used for calcining it. The outcrops of these two beds have been traced from Cobinshaw to several quarries at Townhead, where both were wrought. On the banks of the Longhill Burn there are several shallow quarries now grassed over, and from Addiewell to Addiewell Bridge, the position of the limestone is also indicated by a chain of abandoned quarries.

Between Addiewell Bridge and Blackburn Hall, this bed has not been worked, but the underlying coal has been opened out to the north of Cuthill and found to be 4 feet thick. In the burn to the south of the shooting lodge on Pates Hill, there are two thin limestones which weather with a yellow tint, and are separated by 18 feet of black shale, with ironstone nodules. The lowest band is 1 foot thick, and the upper 4 to 5 feet, and in fresh fracture each is a solid blue-black limestone. These limestones are estimated to lie about 450 feet above the Cobinshaw Hurlet Limestone.

The top of the Cobinshaw Hurlet Limestone is exposed in the Breich Water above Addiewell Bridge, and the overlying beds are shales and soft flaggy sandstones, with two coal seams, one of which has been wrought. Two bands of limestone, 1 foot and 5 feet thick respectively, and separated by 9 feet of fossiliferous shale, are well exposed along the lower portion of the Skolie Burn. They are estimated to lie about 425 feet above the Cobinshaw Hurlet Limestone, and are probably the northern extensions of those at Pates Hill. These limestones in Skolie Burn are succeeded by 50 feet of black shale with nodules and fireclay, overlaid by a dark limestone 2 feet 10 inches thick, with brachiopods. A fourth

Mr. Wilson. limestone, 2 feet thick, lies some distance higher up. It is probable that these four bands exposed in the Skolie Burn are members of the upper division of the Lower Limestone Group, and correspond to the Hosies Limestones of Fife. On the south side of the large east and west fault which crosses Leven Seat, one of these upper bands, in two leaves, is exposed along the crest of an anticlinal fold. On the east side of this plication, and separated from the last mentioned limestone by 190 feet of black shale with ironstone bands, there are two still higher limestones.

The Bo'ness and Bathgate Coal Group.

Mr. Clough. *Bo'ness to Linlithgow.* From the sections in the Snab Pit, and in the bore near No. 9 Pit, Bridgeness, it appears that the total thickness of strata between the Index Limestone and the Carriden Upper Limestone, is about 1,050 feet. This estimate includes several beds of igneous rock, in all more than 300 feet, which are supposed to represent contemporaneous lava-flows, but excludes an intrusive sill which occurs in certain localities. The thickness of coal, including all seams down to a foot in thickness, amounts in these sections to 29½ feet.

The lower division of coals underlying all the lava-flows in the group, includes, among others, the following seams, in ascending order:—the Smithy, the Easter Main, the Six-Feet, the Lower Parrot and Ironstone, and the Red Coal. The chief seams which occur above this division are the Wester Main Coal, the Seven-Feet Coal and Upper Ironstone, the Corbiehall and the Splint, but none of these are at present worked.

The occurrence under the foreshore and the Firth of Forth, of certain of the coals of the lower division, considerably to the east and north of their outcrops inland, is mainly due to the presence of two faults, which strike nearly east and west, and have downthrows to the north. Unfortunately, the mining operations under the Forth are liable to be affected detrimentally by the presence of a deep preglacial hollow—probably part of an old valley of the Forth—at the sides of which the coals terminate against Boulder Clay. This preglacial hollow has already been partly described by by Mr. Cadell,* and will be referred to in the sequel; but it may be mentioned here that in the Bridgeness workings the Red Coal, the Lower Parrot and Ironstone, and the Eastern Main Coal, have all been proved to crop out against it in one place or another.

The seams at present being worked by the Bridgeness Company are the Red Coal and the Eastern Main, but a pit is being sunk to the Smithy which has been proved by a bore to be of good quality in the locality.

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* "Surface Geology of the Estuary of the Forth round Borrowstounness." *Trans. Edin. Geol. Soc.*, vol. iv., p. 2. "Note on the Buried River Channel of the Almond." *Trans. Edin. Geol. Soc.*, vol. viii., p. 194.

All the strata in the Carriden Pit lie below the Red Coal, and the Eastern Main is the only seam worked, but a shaft is being sunk to the Smithy Coal. The more northerly of the two large east and west faults is well exposed in a cross-cut, and its inclination is only about 45° from the horizontal. Mr. Clough.

In the Carriden Colliery, it is noteworthy that immediately above a thin coal which lies 2 or 3 feet above the East Main, there is a band of shale, 2 or 3 inches thick, which is crowded with remains of *Lingula*. This fossiliferous horizon was sought for in the Bridgeness workings and in the Furnace Yard Pit of Kinneil, without success, though the thin coal referred to is present in both localities.

The Six-Feet and the Smithy coals are now being wrought in the Kinneil Collieries, and as they lie considerably to the west of the other collieries, they are sunk to much greater depths, owing to the westerly dip of the strata. In most parts of the district the roof of the Smithy has long been known as a pyritous richly fossiliferous shale, crowded with remains of *Lingula*. In the southerly part of the workings the seam makes an excellent house coal, but the quality deteriorates towards the north. The two coals—the East Main and the Red—which are worked at Bridgeness, only two miles away, are not worked at Kinneil. The Red Coal does not indeed appear to exist there, and the East Main is of a poor quality. On the other hand, the Six-Feet coal, which is not mined at Bridgeness, is wrought at Kinneil, and is there accompanied by a valuable seam of cannel, often about 8 inches thick, which lies at the base.

In expectation of finding the Boness coals in good condition on the western side of the Kinneil workings, Messrs. W. Baird & Co., of Bothwell Collieries, have lately sunk a deep bore, near North Hainings, in a position rather more than a mile west-south-west of the deepest part of the Kinneil Collieries. The results are most disappointing. The bore enters the Index Limestone at 145 fathoms from the surface, and proceeds to a total depth of more than 425 fathoms, but without piercing any coal of value. The position of the Seven-Feet Coal is recognisable at a depth of about 32 fathoms below the Index Limestone, underneath which there is an abnormally large proportion of whinstone and volcanic ash. The characteristic roof of the Smithy coal was not detected, but it seems certain that strata below the position of the Edge Coal group were pierced, for at a depth of 394 fathoms, a limestone, 15 inches thick, is recorded, which, judging from the core, is a dark-grey limestone with fragments of crinoid stems. A higher band, at 268 fathoms, described as a blue limestone, may also be below the position of the Edge Coals.

Discouraging evidence has also been found near Linlithgow. An older bore (No. 6 Kinneil) which was put down near the Little Mill, three quarters of a mile west-north-west of the west end of Linlithgow Loch, and rather more than two miles south east

Mr. Clough. of North Hainings, proves that here also the volcanic rocks in the group increase in thickness for a certain distance towards the west, and that, concurrently, the coals die out or become valueless. The bore begins in a volcanic ash some distance below the Index Limestone and is 691 feet deep. The first sediments are pierced at a depth of 490 feet, perhaps on the horizon of the Wester Main Coal—the position of which is within the thick band of lavas that divide the Boness coalfield into two parts—but they include no coal seam, and are only 7 feet thick. The rocks underneath are evidently, to a large extent, of igneous character, and not a single coal is recorded.

Since the original survey, some newer pits have been opened to the south and west of those which were formerly worked inland, but these have proved unprofitable and have been closed. In a mine about half a mile north-north-east of Upper Bonnytoun, the Smithy, the East Main, the Six-Feet, and the Red Coals were all proved, but the seam of the Lower Parrot and Ironstone was hardly represented. In the Muirhouse Pits 1 and 2, about a mile north of the west end of Linlithgow Loch, the two coals, neither of which exceeded 2 feet in thickness, lie above the great sheets of igneous rock that divide the Bo'ness coal group into two divisions, but it is uncertain to which of the Bo'ness seams they correspond. From such evidence it may be inferred that on the south side of an east and west line drawn about a mile and a half south of the Forth, the coals have a tendency to deteriorate in a southerly direction towards Linlithgow, while, as stated elsewhere, the volcanic rocks are more highly developed.

Mr. Muff. *Cocklerue to the Knock.*—Between the Index Limestone and the lavas overlying the Wardlaw Limestone, there is a group of sediments, including a coal formerly worked at Kipps, which appears to be the only representative of the Bo'ness and Bathgate coals existing in this area.

Mr. Bailey. *Bathgate and Blackburn.*—In the Bathgate district there are four workable coals, namely, the Balbardie, China, Jewel, and Main, the last named being the lowest. Bands of parrot are found in places in all the three upper seams, but the parrot of the Balbardie seam, with the associated black band ironstone, is particularly valuable. Unfortunately, in the workings towards the dip, igneous rocks intervene between this seam and the Index Limestone, and to the west of the Eastern Pit (sunk through the Roslin Sandstone and Upper Limestone groups west of Bathgate) the parrot is rendered worthless. In the future development of this coalfield, the uncertainty regarding the underground distribution of the igneous rocks must always be remembered.

Near Blackburn, to the south of Bathgate, a coal between the China and Jewel Seams increases to workable dimensions, and is known as the Woodmuir Smithy Seam. At this locality none of the coals known at Bathgate contain parrot or ironstone. At the Mossside Colliery, however, situated in an area where the

southerly thinning of the volcanic rocks has taken place, a bore put down this year has proved the existence of a gas coal below the Main Seam, evidently occupying the position of the gas coal known at Foulshiels, two miles to the south, The gas coal in the bore is associated with basalt, but in a southerly direction it may prove of value. Mr. Bailey.

Foulshiels and Woodmuir Area. The structure of the northern portion of this field, as far south as Woodmuir Colliery, is very simple. To the north of the Caledonian Railway, the general strike of the strata is north and south, and the dip westerly at angles from 15° to 20°. On the south side of the railway the inclination is less, and the direction changes to north-west. The field is intersected by several cross-faults that shift the coal crops to east or west, according to the direction of downthrow. As we approach the Levenseat fault the strata begin to undulate, and on the south side of that dislocation the Lower Limestone group arches up through the coal-bearing beds. Mr. Wilson

The following table gives the thicknesses of the various coals at present wrought at the collieries in the area, as well as the thicknesses of the intermediate strata.

	Woodmuir Colliery.	Loganlee Colliery.	Foulshiels Colliery.
China Coal - - -	2 ft. to 2 ft. 6 in.	3 ft. 3 in.	2 ft. 9 in.
Strata - - - -	14 fms.	14 fms.	12 fms.
Woodmuir Smithy Coal -	2 ft. 2 in.	3 ft. 7 in.	2 ft. 6 in.
Strata - - - -	4 fms.	5 fms.	6½ fms.
Lady Morton or Jewel Coal -	2 ft.	3 ft.	3 ft. 10 in.
Strata - - - -	14 fms.	11½ fms.	9 fms. to 12 fms.
Wilsontown Main Coal -	4 ft.*	5 ft.	6 ft. 7 in.

From the above table it is clear that the four coals indicated are thicker at Foulshiels than at Woodmuir; indeed it is the general rule in this area that the coals become thicker towards the north.

In the Lady Morton Seam, at Foulshiels, there is, near the base, a band of Parrot Coal, which varies much in thickness and quality. The Wilsontown gas coal, which lies 25 fathoms below the Main coal, is too thin to work, and has been proved in bores north of Addiewell Branch Railway to be only nine inches thick. This coal is correlated by the local mining people with the Lesmahagow gas coal of Lanarkshire. At Foulshiels the Balbardie coal is not workable, but is known to be 18 to 24 feet above the China coal. The Little Parrot of Balbardie is 2 feet 7 inches thick at Foulshiels, and is seven fathoms below the Index Limestone.

Upper Limestone Group.

Bo'ness to Linlithgow.—Most of the beds of this group, including the Index, the Calmy (Dykeneuk), and the Levenseat Limestones, with the associated strata, are exposed in the River Avon below Mr. Clough

* In two leaves with shale, from four to ten feet thick, between.

Ir. Clough. the railway viaduct between Manuel and Kinneil, where they are disturbed by various faults. From evidence obtained from bores, it appears that near the Forth the total thickness of the group is about 830 feet.

The lowest of these limestones—the Index—was originally mapped as the Calmy, where exposed in the River Avon near Little Mill, about three quarters of a mile north-west of Linlithgow Loch, and is there about 6 feet thick. Above the Index, and separated from it by about 250 feet of strata, there is a thin limestone, about 3 feet thick, visible in that river about 100 yards west of the bridge at Kinneil Mill. It resembles the Index near Little Mill in being crowded with *Productus latissimus* and it is underlain, like it, by an 8-inch coal seam. Mr. Tait, however, detected the following points of difference; first, the occurrence between the Index Limestone and underlying coal at Little Mill of a calcareous mudstone, 1 foot thick, charged with *Fenestella* and a few specimens of *Productus*, which is absent in the corresponding position at Kinneil Mill; second, the band at Kinneil Mill is separated from the underlying coal only by an inch or two of sediment.

Next in order comes the Calmy Limestone, which is seen in the river, both on the north and south sides of a powerful east and west fault. None of the exposures of limestone are complete, but it is evident that the bed is of good quality, at least 6 or 7 feet thick, and overlain by a considerable thickness of shale containing various thin calcareous seams and lenticles. A few feet below this limestone there is usually a coal seam, called either the Wood coal or the Upper Hirst, which has formerly been worked extensively in shallow pits near Dykeneuk and in Kinneil Woods. On the south side of the railway line, 250 yards E. of Dykeneuk, the coal is exposed, and is at least 2 feet 8 inches thick.

A bore sunk 650 yards west-south-west of East Kerse Mains proves that the strata which there intervene between the Calmy and the Levenseat Limestone are at least 240 feet in thickness.

The Levenseat Limestone is not well exposed now, but it has formerly been mined extensively near the north side of the Avon, and the total thickness, including shaly bands, is said to be 7 or 8 feet. The workings extended 600 yards north-east from the outcrop on the north side of the Avon and it is probable that the bed reaches further in this direction before it curves and strikes in a north west or west direction.

r. Grab-am. *Linlithgow to Cocklerue.* The upper limestones of this area were re-examined for the Geological Survey by Mr. Cadell about fifteen years ago, and his conclusions have been generally confirmed. The limestone north of Linlithgow Bridge is now regarded as the Index, and bores have proved that the Calmy and Levenseat bands occur further west. The highest horizon of igneous materials is a fossiliferous tuff just below the Calmy Limestone in Carribber glen.

r. Bailey. *Bathgate and Blackburn.*—Little was known of this group in this district at the time of the original survey, but of late years several

deep bores,* put down to prove the underlying coals, have shown the persistence of the three well known bands of limestone, the Levenseat, the Calmy, and the Index. The most northerly of these bores, a mile and a half north of Bathgate, recorded the occurrence of a thin limestone about 37 feet above the Index, which has not been met with further south. This group contains no valuable coals. No volcanic rocks are known above the Calmy Limestone, though they occur in considerable mass between that bed and the underlying Index. Mr. Bailey

Foulshiels and Woodmuir Area.—In this area the group appears to be about 450 feet thick, and includes nine thin coals, none of which are workable. The Index Limestone is never seen at the surface, but its position has been traced, by numerous bores, from Mosshall to the fault at Blinkbonny. It is usually about 4½ feet thick, and is overlain by a thick white sandstone. The Gair (=Calmy) Limestone is reported (Explanation to Sheet 31, p. 24) to have been wrought in a small quarry at Whitehouse, west of Hendrey's Course, but the quarry is now covered up, and it has not been recorded in any of the bores where it might have been expected to occur. The Levenseat Limestone has been wrought for over 200 years by open cast workings and mines. The mined field and outcrop lie between two large east and west faults, one of which passes through Bankhead, and the other on the south side of Leven Seat. The Limestone, which is about 9 feet thick, is overlain by an oil shale 2 feet 3 inches thick, the lower portion of which is very rich and was mined together with the limestone. For many years this tough leathery shale was sold throughout a wide district for cover plates for the road "culverts," and, although less than 1 foot in thickness, these plates are so strong that heavy traction engines can pass over the culverts without breaking them. In the mined area, this limestone was best at its outcrop and continued good till it reached a depth of 20 or 24 fathoms. At greater depths it deteriorated, both in quality and thickness, and became unworkable. Mr. Wilson

Contemporaneous Igneous Rocks.

Bo'ness to Linlithgow.—The evidence afforded by a number of bores and various rock exposures on the north side of Linlithgow Loch tend to show that the Lower Carboniferous volcanic rocks are more highly developed on the north side of that loch than was previously supposed. Indeed there is no reason to believe that they suddenly increase in thickness south of that locality. Mr. Clough

In the Carboniferous Limestone Series near the Forth, the lowest visible volcanic material is the Carriden volcanic tuff, intercalated between the Carriden Middle and Lower Limestones. In the 1892 edition of the 1-inch map 32, this ash is shown as a neck, but it

* The journals of the more important bores are given in Mr. Cadell's paper already referred to.

Mr. Clough. is mainly composed of fine grained well stratified material inclined at gentle angles in the same direction as the sediments near it, and in Carriden glen it is overlain by the Carriden Middle Limestone. It seems, however, to thin out rapidly toward the west, for it is stated that the bore, about 100 yards west of Carriden Church, about half a mile from the outcrop of ash, did not pass through tuff, though it pierced the Carriden Lower Limestone.

The types of basic igneous material which crop out near Walton and which were formerly supposed to be part of a broad dyke, running nearly east and west, are in part similar to rocks which occur as lava-flows in other parts of the area. One of them is extremely vesicular, and it is probable that some at least are contemporaneous. Their stratigraphical position is probably not far below the Smithy Coal. At the old coal mines north west of Upper Bonnytoun, whinstone occurs almost immediately below the Smithy Coal, and a third of a mile south west of that locality there are exposures of a basic vesicular rock, probably on a slightly lower horizon.

The thick bands of igneous material which occur between the Red Coal and the Upper Parrot and Ironstone vary much in character, but they have not yet been thoroughly examined under the microscope. Some portions are much more massive than others, and perhaps represent the interior portions of flows. Certain varieties show numerous spots of olivine, and it is probable that all can be classed among the basic rocks.

Many of the separate flows appear to be rather thin, and highly inclined streaks of altered sediment, sometimes as much as 2 or 3 inches thick, are often found penetrating their upper surfaces for a foot or more. In a quarry a quarter of a mile northwest of North Bank, three flows are seen, of which the lower is about 30 feet thick, while the middle is 18 or 20 feet. In one place, but not generally, between the lower and the middle flow, there is a parting of sediment, about a foot thick, and several round lumps of vesicular trap are surrounded by sediment. The bottom of the lava flow that overlies the Red Coal is well exposed at the mouth of a day level, nearly half a mile N.N.W. of Upper Bonnytoun. It is very vesicular, and appears to be partly divided into big rounded masses, 2 or 3 feet in diameter, some of which are, to a large extent, if not entirely, isolated from one another by clayey shale.

The thick mass of tuff near the Little Mill north of Linlithgow, that lies not far below the Index Limestone and is separated from it by ashy mudstone and shaly sandstone, is partly exposed in sections, which show it to be well bedded and somewhat gently inclined. In the journal of the bore already referred to, which has been sunk near this locality, all the rock down to a depth of 487 feet is described as "whin," with the exception of thin streaks of coal at 349 feet. But as the highest rock encountered must have been the ash of Little Mill, it is clear that many mineral borers use the word "whin" to include tuff.

In a bore near Kinneil Mills on the north side of Linlithgow Bridge, there is a band of igneous rock, 22 feet thick, which, though not seen in contact with any sediments, is often so vesicular that it seems most likely to be a lava-flow. A bed of igneous rock is exposed on much the same horizon near the Forth, a little north-east of Kinneil railway station. Mr. Cloug

In a little stream 200 yards north east of Kinneil Mill, north-west of Linlithgow, there is a bed of ash, some distance below the limestone at that locality, which is probably the highest volcanic rock in this area. Its position is between the Index and Calmy Limestones in the Upper Limestone group.

Linlithgow to Cocklerue.—The lavas of the district, ranging from above the Two-Feet coal (in the Calciferous Sandstone Series), to a horizon above the Index Limestone, are generally fairly constant in type, being fine grained olivine-basalts, with the olivine alone in conspicuous crystals. The microscope shows abundant, but generally decomposed olivines, and a few smaller augite phenocrysts, in a groundmass, generally holocrystalline, of felspar and augite, the latter often showing good crystal outlines. These lavas are often beautifully columnar, as noted by all the observers who have previously described the district. Slaggy types of softer character are exposed in places, and these also appear to be olivine basalts, but they are generally much decomposed. Below the Index Limestone there is a lava with an unusually low specific gravity, and it is expected that it is of a more acid type. Mr. Grabham.

Olivine basalts, similar to those mentioned above, occur as thin dykes in the volcanic vent at Pilgrim's Hill, 300 yards north-east of the Linlithgow Poorhouse.

Cocklerue to the Knock.—The greatest thickness of the volcanic series of the Bathgate Hills is found along an east and west line stretching from Longmuir Plantation, about three miles south-east of Linlithgow, nearly to Lochcote, about two and a half miles south-west of the same town. Beginning in the east, and following the ascending sequence, we find on both sides of the Longmuir Plantation some distance above the Two-Feet coal and its overlying ash, a thin group of basalts, with tuff; succeeded by thick shales with subordinate sandstones and a thin calcareous bed at the top. Next in order comes the thick mass of lavas forming the Riccarton Hills, which are chiefly fine-grained, dark blue to black, olivine basalts, and including at least one rock distinctly coarser-grained than the rest. Some intercalations of sandstone were noted, but it is difficult to separate the different flows, of which there are, probably, at least eight. The top of the latter group, where the sediments supervene, which include the Tartraven Limestone, is hidden by drift. In the group of lavas above the Tartraven Limestone it is possible to distinguish three flows, the lowest of which has a horizontal platy structure, whilst the topmost is decidedly columnar. Mr. Muff.

Mr. Muff. The position of the Petershill or Silvermine Limestone appears to be immediately above the last named group of lavas, but in this line of section it is nowhere visible owing to the covering of drift. Next in order come a thick group of lavas, occupying the summit ridge of the Bathgate Hills, and comprising black, compact, and columnar rocks, many of them being vesicular and rather decomposed, sometimes with a platy structure. So far as examined they all appear to be olivine basalts. Within this group of lavas the coralline limestone of Wardlaw is intercalated. The sediments above this group include the Index Limestone and the underlying coal, formerly worked at Kipps. A short distance above the Index Limestone there is an ash, surmounted by another group of basalt flows. The overlying strata contain at least one well marked band of tuff, and ashy material is found intermingled with the sediments immediately below the Levenseat Limestone.

Mr. Bailey. *Bathgate and Blackburn.*—Little can be added to Sir Archibald Geikie's history of the volcanic phenomena of the district.* Flows of olivine basalt appear in the upper portion of the Calciferous Sandstone Series, and follow in rapid succession high up into the Bo'ness and Bathgate Coal group. The upper portion of this group is represented by sediments, and includes four valuable coal seams, but above the Index Limestone one or more beds of lava appear, which mark the recrudescence of volcanic activity. South of Bathgate, the igneous rocks thin away somewhat suddenly, and their place is taken by sediments of the same age.

Intrusive Sheets and Dykes.

Mr. Clough. *Bo'ness to Linlithgow.*—The only rock known to be of intrusive character is a basic sheet a little above the Smithy coal at Carriden, formerly regarded as a lava flow, but in the Smithy coal workings, near the Miller's Pit (about 670 yards south-south-east of the old Grange House), it suddenly changed its horizon, and appeared in the form of a white tongue traversing the coal and completely spoiling it.†

Mr. Grabham. *Linlithgow to Cocklerue.*—The most basic intrusive rock noted forms a dyke at Maclure's Crag, about three furlongs south-west of Wester Ochiltree. It is an olivine dolerite in which the olivine has been replaced by green pseudomorphs. The augite is fairly fresh, but part of the felspar is represented by a mass of zeolite, often isotropic, which has lowered the specific gravity of the rock to 2·68.

One of the most interesting features discovered in the course of the revision is the presence among the lavas of large intrusions —generally in the form of sheets—the exact relations of which

* *Mem. Geol. Surv.*, Geology of the Neighbourhood of Edinburgh, 1861, especially chap. vi.

† H. M. Cadell. "The Carboniferous Limestone Coalfields of West Lothian," p. 7. *Trans. Inst. Min. Engineers*, 1901.

to the east and west dykes are not yet definitely ascertained. The large sill at Kettlestone, which is continuous southwards with the igneous mass of Cocklerue, lies directly on the line of one of these dykes, which may be seen both on the west and on the east sides, but cannot be traced through the mass. The exposure of the dyke nearest this sill is not of the usual type but resembles the latter in having pink spots of micropegmatite. A smaller intrusion appears to the west, below the Levenseat Limestone at Bowden Hill. Both sheets usually cut across the strata, and where they occur as laccolites they have produced alteration in both the upper and the lower beds. The petrographical characters of these intrusions are much the same as those of the Whin Sill of the North of England, and of the Stirling and Ratho sheets.* Mr. Grabham.

By most British authors, such rocks have been called dolerites, but they agree closely with the rocks termed quartz-diabases by Rosenbusch.† The large felspars are generally twinned on the Carlsbad law. Albite twinning is not often seen, but a zonary structure may be due to ultramicroscopic twinning on this law. A very pale augite occurs in large plates moulded on the felspar, and has given rise to uralitic hornblende and green decomposition products round its margins. The iron ore is ilmenite which builds large skeleton crystals. These constitutents are set in a ground mass of micropegmatite. The margin of the rock is fine grained and homogeneous, but towards the centre it contains pink or white patches which differ from the surrounding areas in containing a greater proportion of micropegmatite. The latter appears to have played the *rôle* of mother liquor, and, after the separation of the other minerals, has finally collected into patches and veins. Some of the veins are about two inches broad, and cut the finer grained rock. Mr. H. W. Monckton has described similar structures,‡ and Mr. Seymour§ has suggested that they are due to the intrusion of a granophyric magma into an augite-diorite, but were the structure in the present instance due to such a cause, evidence of the intrusion of the granophyric magma would be seen in other parts of the rock. The phenomena must be of an endogenous character.

Cocklerue to the Knock. An irregular intrusion of dolerite, which appears sometimes like a dyke and sometimes like a sill, runs in a general north and south direction along the summit ridge of the Bathgate Hills. It is a rather coarse-grained rock, consisting essentially of plagioclase and augite, with a distinct tendency to an ophitic structure. A chilled margin, transgressing the lavas and ashes and proving the intrusive nature of the dolerite, is exposed in one or two sections. Some evidence was obtained on Cocklerue that smaller intrusions from the same magma accompanied the Mr. Muff.

* Dr. Teall, *British Petrography*, p. 192.
† *Elemente der Gesteinslehre*, fig. 59 and p. 342.
‡ *Quart. Journ. Geol. Soc.*, vol. i. p. 480, 1895.
§ Summary of Progress for 1900, p. 164.

Mr. Muff. main mass of dolerite, and that, in this locality, the sill is a multiple one. It is also probable that the large sheet, shown on the published one-inch map, as stretching from Torphichen, consists of more than one intrusion.

The east and west dolerite dyke, represented on the published one-inch map as passing along the southern margin of the Torphichen sill, appears to run into the irregular north and south intrusion of Cocklerue. The dykes are, however, in some cases, later than the sills, or perhaps the sills are not all of exactly the same age. A very fine section of a dyke cutting a sill is exposed in a quarry at Ochiltree Mill, about three miles south-east of Linlithgow.

Mr. Bailey. *Blackburn and Bathgate.* The southern prolongation of the Cocklerue intrusion traverses the volcanic district east of Bathgate and can be traced as far south as Blackburn. It is faulted in two places, and in each, the outcrop is shifted in a reverse direction to that of the lavas and sediments, because it is usually in the form of a sheet inclined to the east, whereas the bedded rocks generally dip to the west. At the Knock, however, the highest of the Bathgate Hills, it occurs as a great north and south dyke. Whether this dyke is in surface connection with the sheet to the south is uncertain, but there is no doubt that it is part of the same intrusion, and that it cuts through a fine exposure of one of the well known east and west dykes of the central valley of Scotland. The significance of this latter point, noted by Mr. Clough, is great, for it is clear that this doubly faulted sheet belongs to the intrusions of late Carboniferous age, * and, hence, the east and west dyke cannot be ascribed to a later period. This evidence is in accordance with that obtained by Mr. Clough† in the Cowal district where the east and west dolerite dykes are repeatedly cut by those of Tertiary age trending in a north-west direction.

East of Bathgate this sheet of dolerite can be readily followed northwards obliquely across the strike, from the east side of the East Kirkton quarry to the road, where it feeds a fine grained sill intruded among the ashes overlying the West Kirkton limestone. Northwards, it invades the Petershill limestone, but is again truncated by a fault which shifts the outcrop of the limestone to the west, and that of the dolerite to the east.

Mr. Wilson. *Foulshiels and Woodmuir Area.* The "leckstone," which has been classed by Sir A. Geikie with the lavas, has been re-examined in the field and under the microscope. No satisfactory evidence has been obtained, in the field, to confirm his view, and as it is clear that the overlying sediments have been greatly altered, we shall describe this rock and the closely associated dolerite with these intrusions. In the new "leck-stone"

* Sir A. Geikie, *Quart. Journ. Geol. Soc.*, Presidential Address, 1892, pp. 140–143.

† "Geology of Cowal." *Geol. Surv. Memoir*, pp. 139 and 147.

Explanation of Sheet 31, *Mem. Geol. Surv.*, p. 24, and "Ancient Volcanoes of Great Britain," vol. 1, pp. 419 and 443.

quarry, about half a mile south of Blackburn, the top portion of the rock is dolerite and the bottom a rather hard picrite; the divisional line between the two is tolerably distinct, but very sinuous, and does not seem to be due to the chilling of either rock against the other. Mr. Wils

Southwards from this quarry, dolerite occurs at the railway viaduct, and in several quarries to the south, where it was worked for road metal. In the railway cutting the outcrop of the dolerite is 151 yards broad, and not accompanied with any picrite. From this cutting the dolerite has been traced by numerous exposures to Rusha quarry, where the rock face shows about 30 feet of dolerite resting on 15 feet of dark greenish grey picrite. The divisional line appears to be nearly horizontal, but it is not very prominent and there is no chilled margin. The bottom of the picrite is not seen, but there can be no great thickness of rock between the bottom portion of the picrite exposed in the quarry, and the underlying dark sandy shales in the adjoining burn.

A somewhat thinner band, whose top and bottom layers are composed of dolerite with picrite in the centre, lies to the east of that just described, and is separated from it by seventy feet of sedimentary strata.

PLEISTOCENE AND RECENT.

Bo'ness to Linlithgow.—As already stated, the side of a hollow, which probably represents the pre-glacial valley of the Forth, has been met in the Bridgeness workings. The outcrop of the Easter Main coal against the Boulder Clay in this hollow strikes nearly east and west for nearly half a mile, and is rather more than 500 feet below the sea. As the depth of the Forth in this locality is not more than twenty-one feet below O.D.*, the total thickness of the superficial deposits must also be about 500 feet. The distance of this outcrop from the first rock exposed inland, at a height of about sixteen feet, is about 3,250 feet, and so the average slope of the old rock surface must, in this locality, be about 1 in 6†. In the same pit, the outcrops of the Lower Parrot and Ironstone and of the Red Coal, at the side of the hollow referred to, have also been found, and it is clear that it bends sharply towards the south when followed up stream. Nothing except Boulder Clay has been found in the hollow. Mr. Clou

The drift above the high raised beaches in the neighbourhood of the Forth is for the most part composed of Boulder Clay of a dark grey or brown colour, but further south, near the Avon, Linlithgow Loch, Grougfoot, and other localities, there are thick deposits

* Admiralty Chart 114c.

† The average declivity of the present land surface between the shore and the top of the hill between Bo'ness and Linlithgow, is about 1 in 17. In parts of some of the steep Yorkshire dales, *e.g.*, Swaledale and Wensleydale, which are in a Carboniferous Limestone district, the sides of the valleys have an average slope of about 1 in 5.

Clough. of sand and gravel, often arranged in mounds with their long axes running nearly east and west, and in one place reaching a height of 300 feet.

A considerable number of glacial striations have been observed, the directions of which vary between E. and E. 16° S.

A raised beach, with its landward margin at a height of about twenty-five feet, extends through Bo'ness, and for some distance on either side. Two higher raised beaches are also met with, the most persistent of which is about 125 feet above sea level. The latter is well seen in the town of Bo'ness and again further west, near Kinneil House, from which place it can be traced, with occasional interruptions, to Inveravon and for some distance up the Avon.

Grab- *Linlithgow to Cocklerue.*—An interesting series of sands and gravels occurs below the 230 feet level, and is well seen on the banks of the Avon, where it forms the Avontoun ridge. Eastwards, it passes into a conspicuous series of mounds of sand in the hollow in which the town of Linlithgow stands.

Bailey. *Bathgate and Blackburn.*—During the retreat of the great ice sheet a marginal lake seems to have been formed between the ice and the ridge of the Bathgate Hills trending north and south, the overflow from which was gentle and produced no lasting feature. In the earlier stages of retreat it was accomplished round the southern end of the hills at the 500 feet level, and the gravels and sands of Bathgate testify to the amount of detritus discharged into the lake by diverted streams and by the waters of the melting glacier.

Wilson. *Mosshall and Woodmuir Area.*—Nearly the whole of the area is covered with Boulder Clay, which, in the Breich Water and ground to the north, attains a thickness of over 100 feet.

Two peat mosses cover considerable areas in the Breich valley, south-east of Longridge, while the higher moorland area, between Cobinshaw and Leven Seat, is covered with black hill peat, often ten feet thick. In the past, these mosses were used for fuel.

ECONOMICS.

Clough. *Bo'ness to Linlithgow.*—New sinkings are at present in progress both at Kinneil, Bridgeness, and Carriden, and it is expected that a considerable development of mining will shortly be witnessed, particularly under the Forth.

Save in deep positions towards the dip, the coals, which can be profitably worked, seem for the most part to have been already taken out of the land side, but it is stated that in certain of the old workings about half the coal has been left in stoops and that it might be profitable to open these old mines and extract the remainder, though the drainage expenses would be considerable.

The Wood Coal, under the Calmy Limestone, does not appear to have been worked except in shallow mines, but it is not placed in the first class.

The washings from each of the seams—the Smithy and the Six-feet—which are mined at Kinneil, are finely powdered and made into coke in ovens at the Snab pit. Mr. Clou

It is stated that the Lower Ironstone has been entirely worked out, but that parts of the Upper Ironstone remain unwrought, even in positions in which it is of good quality and easily accessible. None of the limestones are at present worked.

The largest freestone quarries are those in the bed, about 70 feet thick, a little above the Index Limestone near Kinneil; the upper half of which yields the best building material. At the east end of Bo'ness there are smaller quarries in the freestone which forms the roof of the Red Coal.

The lava flows between the Red Coal and the Upper Ironstone are quarried in several places, but only locally for road metal. The intrusive sheet of basic rock above the Smithy coal is not quarried, and is considerably decomposed near the surface.

At Bo'ness, considerable tracts of the foreshore have lately been reclaimed, and the work is still in progress, to acquire land for sites of houses, saw mills, and other public works, but not for agricultural purposes. On either side of the town there are enormous tracts of flat muddy foreshore which could be converted into "carse" land, but perhaps not at present with any pecuniary advantage.

Linlithgow to Cocklerue.—Good road metal is supplied by the fine grained columnar basalts, and the big intrusive sheets are quarried for all kinds of paving material, part of which is carried for considerable distances outside the district. The finer grained "blue" rock is more durable than the coarse patchy variety, but the value of both is impaired by the presence of the larger pegmatitic veins. Mr. Grabham.

Bathgate and Blackburn. The leading industry of Bathgate and the district to the south is coal mining. At Bathgate the valuable parrot and ironstone of the Balbardie seam is chiefly sought after, but to the south, at Blackburn, none of the proved coals contain parrot, and ordinary bright coals are alone mined. Mr. Baile

Bricks and tiles are made from an alluvial clay west of Bathgate, but the attempt now being made to manufacture artificial sandstone from the drift sands is of special interest. The process is a French one, and consists in subjecting a mixture of sand, lime, and asbestos, first to pressure, and then to the action of steam. By being pressed into moulds the mixture is shaped into bricks of any required size, which retain their shape when subsequently heated by steam.

Mosshall and Woodmuir Area.—Foulshields, Loganlee, and Lower Woodmuir, are the working collieries at present, while Stoneyburn, and the pits between Blinkbonny and Miller's Moss, are all dismantled. Mr. Wilso

At Foulshields colliery a brick work has just been started, The material used is a mixture of shale, brought from Cleland, and

Wilson. of boulder clay dug from a pit alongside the works, and separated from the boulders and large stones. The brick making machines are manufactured by Bradley and Craven, and the kiln used is based on the "Newcastle" plan, with five chambers, which, when in full working order, can turn out 10,000 bricks of good building quality per day.

About forty years ago, when the oil companies first began operations, the oil shale at Leven Seat was retorted and refined in a small work near Greenburn. At that period the price of paraffin oil was high and the work proved remunerative. When prices first began to fall the refining was discontinued and the crude oil sold, but about ten years ago the work was entirely stopped owing to the low price obtained.

The Curdly ironstone lies eight and a half fathoms above the Leven Seat limestone and at one time was extensively wrought, both by pits, mines, and open cast, between Breich Station and the Gladsmuir Hills. It is a clayband nodular ironstone, varying from a few inches to two feet in thickness, and lies in a thick bed of black shale. It was calcined at Wilsontown, and was the richest deposit of its class in Linlithgowshire, yielding as much as 95 per cent. of iron, but at present it is not wrought.

Limestone quarrying is carried on at Cobinshaw and Leven Seat. At the former locality the Cobinshaw Hurlet bed produces a very superior line which finds a ready market in Edinburgh, Glasgow, and the surrounding districts.

A thick decomposed sandstone, lying above the Curdly ironstone at Leven Seat, is quarried and sent by rail to various towns and villages in the surrounding district for building purposes and for making concrete. Some years ago, a quarry was opened to the N.E. of Miller's Moss, for the purpose of producing building stone and grindstones, but the rock proved too soft and was found to possess a detrimental concretionary structure.

The "leckstone" or picrite, which is quarried at Rusha and half a mile south of Blackburn, has an usually low conductive power for heat, and has, for this reason, been long used in Scotland and the north of England, to line the soles of baker's ovens.

Nearly all the road metal used in the West Calder district south of the Breich Water, and as far as the county boundary, is taken from Kaimes Quarry, near Dalmahoy. In Linlithgowshire the roads around Blackburn, Whitburn, and Longridge, have been for a number of years supplied almost exclusively from the Bowden Lime Company's quarry at West Craig Station.

II.—PALÆONTOLOGICAL WORK.

. Peach. The palæontological department in Scotland has been carried on under the general charge of Dr. Peach, Acting Palæontologist, by Dr. Crampton, and Mr. R. G. Carruthers, assisted by Mr. A. Macconochie and Mr. D. Tait, while the following specialists,

Dr. R. H. Traquair, Dr. Wheelton Hind and Mr. R. Kidston, have, Dr. Peac
as formerly, given their invaluable aid.

The number of fossils collected during the year and entered in the Survey list books amount to 971, chiefly from the Carboniferous rocks of the Lothians and Peebles-shire, and from the Upper Old Red Sandstone of Roxburghshire and Mid Lothian.

After a preliminary examination the fossils have been distributed as follows: The fishes have been submitted to Dr. Traquair, the lamellibranchs to Dr. Wheelton Hind, and the plants to Mr. Kidston, while the other forms have been retained for determination by the survey officers.

Fossils to the number of 1,632 have been named and entered in the Survey list books during the year. Of these Dr. Peach determined 171, chiefly higher crustacea, from the Lower Carboniferous strata, Dr. Crampton, 740, miscellaneous forms from the Carboniferous formation of the Lothians and Mr. Carruthers, 73, from the Wenlock rocks of the Pentlands.

Dr. R. H. Traquair, F.R.S., has furnished the following note on Fish Remains collected by the Geological Survey of Scotland in the sandstones of Salisbury Crags, Craigmillar, Torduff Reservoir, and Clubbiedean Reservoir.

"The fish remains from these localities, which have been sub- Dr. Traqu
mitted to me, consist of fragments, mostly very small, of bones, teeth, and scales, and are consequently, in most cases, undeterminable. From Salisbury Crags, however, a number of fragments of conical teeth have been obtained, the fractured surfaces of which show the unmistakable Dendrodont structure of *Holoptychius*, the vascular canals filled with dark red oxide of iron showing clearly against the bluish white dentine. There is also a nearly entire scale, one inch in length, showing mostly the smooth or attached surface: but at one part the scale substance has sprung off in such a way as to display in impression the well known wavy ridges or 'wrinkled' ornamentation of *Holoptychius nobilissimus*, Agassiz.

The remains from Craigmillar quarry are still more fragmentary than those from the sandstone underlying Salisbury Crags. I have found no teeth nor portions of teeth among them, but one portion of a scale is, from its characteristic wrinkled ornament, distinctly referable to *Holoptychius nobilissimus*.

The family *Holoptychidæ* is not known to extend upwards beyond the Upper Devonian (Old Red Sandstone) strata, as the Carboniferous species referred to *Holoptychius* by Agassiz belong to another family, namely, the Rhizodontidae. The species *Holoptychius nobilissimus*, Agassiz, is also a very characteristic or 'leading' fossil in the Upper Old Red Sandstone of Scotland.

Numerous comminuted bony fragments have also been found in the sandstones at Torduff and Clubbiedean Reservoirs. None of these are determinable specifically, and few are even referable to their families.

Traquair. From Torduff may be noted :—

Family Cestraciontidæ. Fragment of a fin spine; external surface not shown; possibly referable to *Sphenacanthus*.

Family Rhizodontidæ. Fragments of teeth and scales.

From Clubbiedean :—

Family Cestraciontidæ. Fragment of a fin spine, resembling that noted above from Torduff.

Family Rhizodontidæ. Fragments of scales.

Family Ctenodontidæ. Operculum, and fragments of ribs of a Dipnoan fish, possibly *Ctenodus* or *Sagenodus*.

From neither of the last two localities have I been able to determine any remains as belonging to *Holoptychius* or any other characteristic "Old Red" genus, and the fragments noted above are not decisive as to the Devonian or Carboniferous age of the beds in which they occur. Their general *facies* seems to me, however, to point rather to the latter than to the former conclusion."

The following is a list of specimens in the Scottish Collection figured in the volume of the Palæontographical Society for 1904 :—

The Fishes of the Old Red Sandstone, by Dr. R. H. Traquair. Part II. No. 2.

Bothriolepis major, Agassiz sp. From Rosebrae Quarry, near Elgin. Plate XXVI, fig. 1.

A Monograph of British Graptolites, by G. L. Elles and E. M. R. Wood. Part IV.

Dicellograptus anceps, Nicholson. From Ettrick Bridge End. Plate XX., fig. 3^{d}.

Dicellograptus intortus, Lapworth. From Carco, Crawick Water. Plate XX., fig. 4^{b}.

Dicellograptus sextans var. exilis. Elles and Wood, sp. nov. From Wandel Water, Abbington. Plate XXI., figs. 2^{c} and 2^{d}.

Dicellograptus angulatus. Elles and Wood, sp. nov. From Morroch Bay. Plate XXI., fig. 4.

Dicranograptus rectus. Hopkinson. From Laggan Gill, Glengonner Water. Plate XXIV., fig. 4^{c}.

Dicranograptus celticus. Elles and Wood, sp. nov. From Glentewing Burn, Duneaton Water, and Rein Gill, Wandel Water. Plate XXIV, figs. 5^{a} and 5^{b}.

Dicranograptus ramosus var *spiniferus*, Lapworth, M.S. From Railway cutting, Kirkton. Plate XXIV., figs. 8^{ac}.

Dicranograptus Nicholsoni. Hopkinson. From Craigmichan Scaurs. Plate XXV., figs. 1^{h} and 1^{g}.

3. MUSEUM WORK.

Mr. Goodchild. Mr. Goodchild, Curator of the Geological Survey Collections in the Royal Scottish Museum, Edinburgh, reports that a number of recently published maps have been placed on exhibition and that the localities of the respective rock specimens relating to these sheets have been indicated by pins, in the usual manner. The intercalation of additional rock specimens in the collection and the renewal of maps has necessitated a good deal of work in connection with the numbered pins, employed for locating the specimens.

A set of rock specimens from the island of Rum, collected by Mr. Harker, has been exhibited in a special case and arranged under instructions from Mr. Harker.

The specimens of rocks and fossils not placed on exhibition in the Museum have been gone over with the view of finding out the number of Duplicates.

In connection with the palaeontological collection, Mr. Goodchild reports that several specimens of Ludlow and Downtonian fishes, hitherto under examination by Dr. Traquair, are now exhibited in the cases, including some which Dr. Traquair has figured and described. Specimens of the higher crustacea, recently obtained from Haddingtonshire have also been placed in the cases.

The zonal forms of fossils are now being indicated by coloured labels and the types and figured specimens are also being marked.

III.—IRELAND.

FIELD WORK.

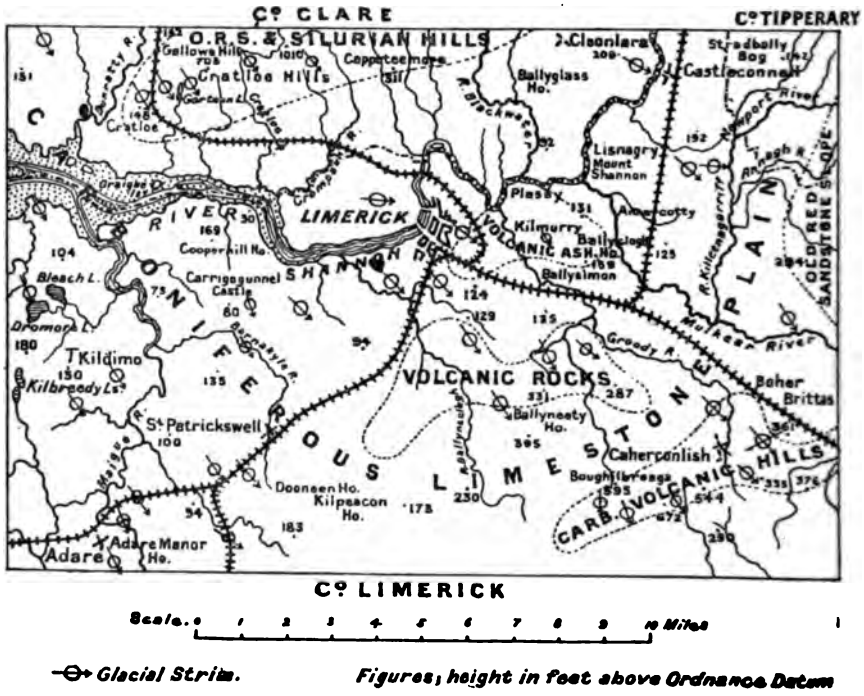
Limerick District.

Mr. G. W. Lamplugh, District Geologist.
Mr. B. S. N. Wilkinson
Mr. J. R. Kilroe
Mr. A. McHenry
Mr. H. J. Seymour, B.A.
Mr. W. B. Wright, B.A.
} Geologists.

The field-work of the staff in Ireland during 1904 was concentrated upon the mapping of the superficial deposits in the country around the city of Limerick. As the city lies near the eastern margin of Sheet 143 of the Ordnance Survey one-inch Map, it has been necessary to arrange for the production of a special "Limerick District" sheet, to correspond to the special sheets of Belfast and Cork on which the work of the two preceding years is published. This Limerick District map will be of the same size as the ordinary one-inch sheets, viz., 12 miles × 18 miles, covering an area of 216 square miles, and it will comprise the eastern two-thirds of the Ordnance sheet No. 143 along with the western one-third of sheet No. 144 (see fig. 2). The survey of

Fig. 2.

INDEX TO LIMERICK SHEET



the Drifts of this tract was taken in hand during the early spring and was completed before the end of the year. The western portion of the tract, south of the Shannon, was surveyed by Mr. McHenry, whose work also extended along the southern part of the map eastward to Rochestown ; Mr. Seymour was responsible for the central part around and including the city of Limerick ; Mr. Kilroe, whose field-work was twice interrupted by serious personal injuries through accidents, mapped the greater portion of the eastern part of the sheet ; the tract in County Clare, north of the Shannon, was surveyed in part by Mr. Wright and was completed by Mr. Wilkinson on Mr. Wright's transference to England ; and a small area in the north-eastern corner of the sheet, extending into County Tipperary, was mapped by Mr. Lamplugh.

Save for the commercial industries of Limerick City and its immediate surroundings, the district is pre-eminently agricultural and the population scattered ; the small towns of Castleconnell and Adare lie respectively within the north-eastern and the south-western corners of the map, and the countryside is dotted with the small villages and hamlets characteristic of a farming community.

The dominant feature in the physiography of the district is the great River Shannon which enters the map on the north-east, and after flowing south-westward for five miles, makes a wide bend to the westward and follows a sinuous westerly trend across the map. In the lower part of its course, up to about two miles above Limerick, the river is tidal ; but between the place where it enters the map, near Castleconnell, and its westerly bend, its current is swift, and in places broken into rapids by rocky ledges (of which the best example is found at the celebrated "Leap of Doonass") so that continuous navigation is impossible. Communication between the more placid waters above and below this broken reach is carried on by means of a canal lying to the west of the river. In the upper part of its course this canal follows a pre-glacial hollow deeply filled with Drift, but leaves it to join the Blackwater River, while the hollow is continued southward until it meets the Shannon again at the great bend.

There are some interesting physiographical problems in association with the Shannon, which will require the examination of a wider area than has been actually surveyed before they can be satisfactorily discussed. It appears to be only since glacial times that the river has attained its present dimensions ; and although its present course between Killaloe and the intake of the canal below O'Brien's Bridge probably coincides with a pre-glacial valley, the river loses touch with this valley before reaching Castleconnell, and has cut a new channel for itself across a hummocky lowland of Carboniferous Limestone and Glacial Drift ; and not until it reaches Limerick does the river permanently recover the pre-glacial hollow. Taking into consideration the powerful volume of the Shannon, the rapidity of its current below Castleconnell,

and the readily erosible character of the rocks over which it flows, it is remarkable that the post-glacial trench cut by the river should be still so shallow and ill-defined, especially when we compare it with the deep gorges which have been cut since glacial times by much smaller streams in adjacent parts of the country. As a rule, we find that above its tidal portion the present river in moderate flood occupies the whole breadth of its trench, and that there is a remarkable absence of terraces of gravel or alluvium, or of any indication that the stream has materially deepened or widened its channel since settling into its present course. Nearly all the lobes of alluvium that occur along its banks may be recognised as deltaic deposits of the tributary streams, or as the result of back-water floods in hollows contiguous to the river, that were previously in existence. The fact that the river is strained of its coarser sediments in passing through the lakes in its middle reaches may explain some of the phenomena; but the evidence seems also to denote that its present course between Castleconnell and Limerick is essentially post-glacial; and moreover, that, contrary to general rule for Irish rivers, the stream has not been appreciably more powerful than at present since its establishment.

The Shannon receives several important tributaries in the district covered by the recent survey, including the Mulkear and its branches, draining from the mountainous ground along the border of Counties Limerick and Tipperary; the Maigue, flowing northward across the limestone country, and falling into the estuary near the western margin of the map; and the Bunratty, symmetrically opposite to the last, draining southward through the north-western part of the map, in County Clare.

The geological framework of the country is simple and is closely reflected in its physical features. The high ridge north of the Shannon in County Clare, which attains a height of about 1,000 feet at the northern margin of the map, is due to a faulted anticline or elongated dome, ranging east and west, which brings up a nucleus of Silurian Slates, with thick masses of Old Red Sandstone dipping away from it on both sides; but only the southern slope of the anticline falls within the present map. A similar, though very much larger anticlinal dome, of which the Slievefelim Mountains form part, occurs a little to the east of the north-easterly portion of the map; and under the influence of this anticline, the Old Red Sandstone again rises to the surface, giving rise to steep hill slopes just within the north-eastern margin of the new map. In both cases the Old Red Sandstone in dipping away from the anticline is soon carried beneath the overlying Lower Carboniferous rocks, which occupy all the rest of the map. Of these, the predominant member is the Carboniferous Limestone, which is the prevalent rock throughout the central and western part of the district, forming an irregularly undulating lowland, principally drift-covered, but with hills and hummocks of bare limestone rising in many places above the general level, especially in the western part of the map.

Associated with the Carboniferous Limestone there is an irregular series of contemporaneous volcanic rocks, which are perhaps the most interesting feature in the "solid" geology of the Limerick district. These consist in part of volcanic ashes, sometimes interbedded with the limestone, and in part of massive basaltic and trachytic lavas and intrusive bosses, that in some cases are believed to mark the actual site or throat of an ancient volcano. The ashes weather at approximately the same rate as the surrounding limestones and do not give rise to marked features; but in the south-eastern quarter, in the neighbourhood of Caherconlish, the massive rocks jut out of the limestone country in bold and sometimes craggy hills. At the extreme south-eastern edge of the area surveyed, the margin of a tract of Carboniferous shales and sandstones which overlie the limestone is reached, and these constitute stratagraphically the highest "solid" rocks included in the map.

Overlying the solid rocks in every part of the district and at all elevations, though mainly on the lower ground, are the Glacial Drifts. The mapping of these drifts and of the later superficial deposits was the direct purpose of the recent survey. It was found that, contrary to expectation, the predominant direction of glaciation was transverse to the Shannon and trended mainly south-eastward, *i.e.*, away from and not toward the western coast. The information collected shows that the ice-sheet which covered the country was sufficiently thick to overwhelm every part of the district surveyed, with the possible exception of the summit of the high ridge in County Clare, where there is a lack of definite evidence. The following particulars with regard to the superficial deposits are compiled from the reports of the individual officers engaged in the field-work.

Commencing with the portion of the map in County Clare north and west of the Shannon, Mr. B. S. N. Wilkinson reports that the undulating ground west of the broad alluvial flat of the Bunratty River, chiefly grass land, is almost entirely occupied by solid Carboniferous Limestone, thinly covered with soil and probably with a little drift in the hollows in places. There are, however, a few well-marked drift ridges, forming grassy features with a north and south direction; and a few hog-backed ridges of drift having the same direction rise above the flat land bordering on the Shannon to the south and south-west of Bunratty Castle. Mr. Wilkinson.

To the east of the Bunratty River the ground rises sharply into the ridge of Old Red Sandstone and Silurian rocks already referred to, and all along the southern slopes of this ridge, the glacial deposits are thickly banked, consisting mainly of a sandy boulder-clay, derived principally from the waste of the Old Red Sandstone, though occasionally including a small quantity of Carboniferous Limestone *débris*. A few boulders of porphyritic granite, like that which occurs in places in County Galway, were also noticed, similar to those mentioned in the previous Memoir ("Explanation of Sheet 143," p. 33). This drift mantles the slopes to a

Mr. Wilkinson. considerable height, reaching, for example, the 700-foot contour line at a little to the east of Gallows Hill, and 650 feet in the Cappateemore valley; while there are numerous small patches at still higher levels. It is well exposed in the deep ravines of the little streams that drain southward from the mountain. There is a considerable difference between the drift bordering the Old Red Sandstone area and that which occurs in the Carboniferous Limestone country distant from the hills; the Boulder-clay in the latter case, being derived mainly from the limestone, assumes a grey or bluish colour and is much less sandy. The red sandy boulder-clay has, however, been carried southward for some distance over the limestones.

Where glacial sands and gravels occur in association with the red boulder-clay they are often difficult to distinguish from this clay in the absence of clear sections, as the difference of soil is not well marked. Moreover, the unstratified boulder-clay appears in many places to merge gradually into stratified sand and gravel of similar composition. The more conspicuous masses of sand and gravel occur mainly along the flanks of the valleys, where they are usually heaped up in elongated mounds, which, when revealed in section, show the arched and contorted bedding characteristic of eskers. Mounds of this kind occur in the Cappateemore valley, and along the margin of the Blackwater; and a broken chain of similar mounds appears to run southward from the Blackwater near Ballyglass House to the Shannon half a mile west of Plassy Lock.

Besides the evidence for the direction of ice movement afforded by the transport of material, there are numerous places on the flanks of the Old Red Sandstone hills where the rock-surface is strongly glaciated. With one exception the striæ observed in these places maintain an average direction of N. 25°. W. to S. 25° E. —the exceptional direction being N. 10° W. to S. 10° E.—though on the lower ground near the Shannon the direction changes to E. 20° S.

The flatter portions of the uplands are in some localities thickly covered with accumulations of peat, but the original extent of these deposits has been considerably reduced by the continuous working of the turbaries for fuel. From the same cause some smaller patches on the lower ground south-east of the hills have been completely removed, while others are nearly exhausted.

Mr. Wright. The area surveyed by Mr. W. B. Wright lay between the Shannon and the Cratloe Hills in County Clare, extending westward to the Bunratty River and eastward to the Crompaun River; it comprises a portion of the southern slope of the ridge of Old Red Sandstone, with the low ground at its foot.

The mapping of the drifts in this tract suggests that the ice-flow coming from the north and west and impinging on the northern slopes and western shoulder of the ridge was partly fended off by the high ground, so that the flow over the hills was limited

in amount, and the area under their lee, where the ice-pressure was lowest, was favourably situated for the accumulation of thick drift. Mr. Wrigh

Another result of this interruption to the ice flow was that congestion and high pressure was caused where the ice rounded the western flank of the ridge, whereby the Old Red Sandstone in this quarter has been scored and planed down in a very striking manner. These areas of deposition and erosion are in marked contrast; the former being characterised by long wet slopes of boulder-clay, and the latter by a comparatively dry craggy hillside with small cultivated patches of drift between the glaciated knolls of rock and ledges of smoothly-planed sandstone thinly covered with turf. On the low ground to the south and south-west of Cratloe the boulder-clay takes the form of drumlins with axes parallel to the direction of the ice-flow, as indicated by the striæ on the adjacent hill-side.

Glacial gravels of the usual type, intercalated between two bands of boulder-clay or rising into mounds from beneath the boulder-clay, are common in most parts of the district. But on the slopes north of Burtonhill House there are some thick deposits of red sand and gravel, locally known as "rabbit-sands," which differ from the rest by reason of their peculiar position and arrangement. These sands form a rudely crescentic terrace-like ridge stretching across the valley of the Cratloe River. This ridge is remarkably flat-topped and steep-sided, the northern slope, facing the hills, being even steeper than the southern, which faces the low ground. Its features are best explained by supposing the deposit to have been accumulated between the margin of the general ice-sheet which hugged the southern slope of the hills and the front of a smaller lobe which came over the hills and down the valley of the Cratloe River. The ridge has been deeply trenched by the present stream, and in a minor degree by several overflow channels which are now dry. These overflow channels probably carried off, either at successive stages or simultaneously, the frontal waters of the smaller ice-lobe. At their northern ends they are not cut much below the top of the terrace, so that it may fairly be presumed that on the further retreat of the smaller lobe there would be an area of slack water to the north of the gravel ridge. The existence of this slack water and the consequent checking of the erosive effect of the waters draining from the lobe explain the preservation of a small linear esker which lies in the hollow to the north of the sands.

The elevation of Neolithic times which is so well marked by the post-glacial raised beach of the north-east of Ireland does not appear to have affected the present district. There are indeed, on some of the smaller islands of the Shannon estuary, faint indications of erosion and deposition at a slightly higher level than that of present high-tides, as for example on an island at the mouth of the Bunratty River where estuarine mud, now undergoing erosion,

Mr. Wright. is seen above high-tide mark, and on Graigue Island where there is a low cliff of boulder-clay, now overgrown by vegetation, with its base at about two feet above the level of recent spring-tides. But in places where reclamation of tidal areas has been carried on so extensively as in the Shannon estuary, it is not impossible that a slight effect of this kind may be due to human interference with the tidal flow of the channel.

Mr. McHenry. The western part of the map south of the Shannon was surveyed by Mr. A. McHenry, who reports that over much of the ground west of the Maigue River the Carboniferous Limestone occupied the surface, often in the form of bare craggy rock with accumulations of soil and thin drift in small hollows only. In working southward, however, the drift was found to increase in quantity, so that it sometimes deeply covers the limestone over wide tracts. The most prevalent kind of drift is a brown loamy boulder-clay, mainly derived from local rocks, but with a few far-travelled boulders, among which blocks of the Galway granite are most conspicuous and most easily identified. In the northern portion of the area this boulder-clay contains much well-glaciated material derived from the outcrop of the Old Red Sandstone lying to the northward, along with the *débris* of the Carboniferous Limestone, the latter becoming predominant farther southward. In the places where the Carboniferous Volcanic rocks have their outcrop, a trail of boulders of these rocks may be traced south-south-eastward from the exposures, as, for example, near Carrigogunnel and around Kilpeacon. The direction of ice-movement thus indicated is confirmed by the evidence of the glacial striæ, which throughout this area are directed from N.N.W. to S.S.E. Twenty examples of these striæ were observed in the area under description.

The boulder-clay is occasionally heaped up into the drumlin form, with the longer axis in the direction of ice-movement, of which an example may be seen about a mile westward of St. Patrickswell; but near Bolane House, one mile west of Kildimo there is a steep-sided ridge of gravelly clay, full of huge boulders of limestone, which strikes east and west and is probably of morainic character.

Of the numerous limited tracts of glacial sand and gravel that occur in the area under notice, the more interesting are those which assume the esker form. The best instance occurs within the demesne of Adare Manor, where a well-defined ridge of sand and gravel running N.N.W. to S.S.E. may be traced for over a mile: and other examples, of less length and more irregular character, were observed just north of St. Patrickswell village, north of Kildimo, and in other places. In other localities the stratified drift occurs irregularly spread around bosses of the solid rock which probably facilitated the melting away of the ice in their neighbourhood; or in low more or less isolated mounds at the margins of of hollows in which later alluvium has been deposited. In a gravel-pit in the St. Patrickswell esker several rounded blocks of the Galway granite were observed, together with other far-travelled

rocks, recognisable as having been derived from the north. The same pit exhibited some remarkably fine examples of folding, puckering, and overthrusting in the laminated finer beds, probably due to movements when the mass was partly frozen. Mr. McHenry.

Owing to the generally low level of the country and to the irregular manner in which the drifts were deposited, many small ponds or shallow lakelets were formed on the withdrawal of the ice-sheet, in which post-glacial alluvial deposits have accumulated. By gradual silting up and drainage, these in most cases became converted into peat bogs, and many have since been drained by artificial means and wholly or partly reclaimed. In two places in the district, however, these little basins still hold shallow sheets of water, viz., at Dromore, where Bleach Lough and Dromore Lough represent the shrunken waters of a single hollow, and at Kilbreedy, where similar conditions prevail. In these basins there is usually a white or greyish shell-marl, crowded with *Limnea*, *Bithynia*, and other fresh-water shells, and above this, a varying thickness of peat, which in most cases has been largely cut away for fuel.

Extensive tracts of grey loamy alluvium border the River Maigue along its course from Adare to the Shannon, expanding into a wide flat, reclaimed by embankments, in the tidal portion of river. Above Adare, half a mile east of the Manor House, there is a flat tract of stiff reddish-brown clay that appears to represent the finer material derived from the washing of boulder-clay; and another deposit of similar character occurs along the tributary stream west of Adare; but until the country to the southward of the present map has been examined, the relation of this material to the recent alluvium must remain doubtful. The clay would probably be suitable for brick-making.

The area surveyed by Mr. H. J. Seymour around and including the city of Limerick lay chiefly to the south of the Shannon, but comprised also the small portion of the county of Limerick that extends northward across the Shannon up to the Crompaun River. Mr. Seymour.

Mr. Seymour reports that the westerly portion of his ground north of the Shannon consists of a wide alluvial flat, out of which rises the higher ground of limestone to the eastward, partly covered with boulder-clay. In two or three places, small areas of the rising ground are completely surrounded by the alluvium, so that they form, as it were, islands. The alluvium consists principally of a stoneless bluish-grey clay, with some organic débris and a little lime, and it has been dug in several places for the manufacture of bricks, but this industry is now carried on in two localities only. Remains of *Megaceros* have been recorded from this alluvium.

On the south side of the Shannon, the greater part of Limerick city is built on a slope of bare limestone, the irregularities of which are now obscured by artificial levelling. In one large but partly obliterated depression, however, under the vicinity of the People's Park and St. Michael's Church, excavations for foundations and drains have proved the presence of over 27 feet of drift-material,

Mr. Seymour.

namely a fine "puddling-clay" with some boulder-clay and a little gravel. Borings near Nelson Street and Mulgrave Street have also indicated a minor depression filled in with boulder-clay and local detritus.

East of Limerick, up to Kilmurry Church, the Carboniferous Volcanic rocks occur at or close to the surface in several rather extensive tracts, chiefly on the higher ground, but with much glacial drift, including both boulder-clay and sand and gravels, in the intervening spaces, the latter variety being principally developed on the higher part of the slopes overlooking the valley of the Groody River. Where the boulder-clay includes much material derived from the volcanic ash, it generally yields a loose friable soil that is well adapted for market gardening, and is extensively tilled for this purpose. Toward its confluence with the Shannon, the Groody River develops a wide flat of clayey or loamy alluvium, in part subject to floods.

South of Limerick, the ground extends for three or four miles as a gently undulating plain, rimmed farther southward by the bold hills which mark the outcrop of the harder members of the Carboniferous Volcanic series. The greater part of this plain is overspread by drift, through which the Carboniferous rocks protrude only here and there in limited exposures. The prevalent superficial deposit in this tract is boulder-clay, with minor areas of peat-bog and alluvium, and with a sparse development of glacial gravels occurring as small isolated mounds, and occasionally as eskers. The boulder-clay is a typical "till" with many scratched stones, and, except in the immediate vicinity of the volcanic rocks, is mainly composed of Carboniferous Limestone débris. It often contains very large slabs of limestone, so that it is difficult at times to decide whether one is dealing with rock *in situ* or with drift. The quarry-sections show that in most places the uppermost beds of rock have been much disturbed by the passage of the ice-sheet, so that massive bands of limestone are frequently broken up and the pieces twisted out of position and sometimes completely incorporated with the boulder-clay. Where the rock was unequally disintegrated prior to the glaciation, the ice-sheet has cleared away the less resistant portions, forming gullies that are now filled in with a much-tumbled boulder-clay. Sometimes the beds of limestone have been pushed forward so that they form a roof over these little valleys; in other cases, thin bands of rock have been carried along in the boulder-clay and twisted into S-shaped folds, the component fragments of the band still maintaining general continuity. These phenomena are well seen in the quarry near Ballysimon, where the rock-surface beneath the tumbled boulder-clay is well striated.

Far-travelled erratics are rare in the boulder-clay, but a few have been noted, lying on drift-covered surfaces, including the characteristic quartzites, granite and green schists of Connemara, the most interesting being an erratic closely resembling the Connemara "money-stone" (a sillimanite gneiss).

Mr. Seymour.

The stratified drift, as previously noted, besides occurring in isolated mounds and ridges on hill slopes, and sometimes intercalated in the boulder-clay, is also in one or two places heaped up into short ridges of the esker type, and then often reveals disturbed structures similar to those mentioned above by Mr. McHenry. These structures are particularly well seen in the sand and gravel pits east of Doneen Bridge, where the esker is about 40 feet high and has originally extended for over a mile in a south-easterly direction. The disturbances are mainly reversed faults, occurring at short intervals in parallel series, one of the clearest examples showing a lateral movement of about 2 feet. In addition, there are minor crumplings and foldings recalling in places the structures seen in plicated gneiss. It is evident that there has been a compression of the material subsequent to its deposition, which might be explained in this case by supposing the bottom of the esker to have originally rested on ice which, in melting, lowered the mass of stratified material to the ground within a progressively narrowing channel.

In the alluvial hollows, the greater part of the peat has been now removed, and the deposits of white shell-marl which frequently underlie the peat are in such cases covered only by a thin peaty soil. In a tract of this kind to the S.S.W. of Donaghmore Church, some shallow excavations revealed the presence of numerous large boulders with partly obliterated glacial scratches, apparently embedded in the marl; but it was found on further examination that the bases of these boulders rested on tough clay or on coarse shingle, and they may therefore be regarded as the residual material remaining after the erosion of the boulder-clay by late-glacial flood-waters.

A broad tract of alluvium lies to the south-westward of Limerick City, where a small stream—the Ballynaclogh River—joins the Shannon. The clay of this tract is occasionally sandy, and sometimes marly owing to the presence of fresh-water shells. It was formerly excavated for brick-making, and the more clayey portions have recently been tested and found suitable for use, in conjunction with the local limestone, for the manufacture of Portland cement.

The general direction of the glaciation, as indicated by the glacial striæ observed by Mr. Seymour in about twenty different localities is from north-west to south-east, but with a more definitely easterly trend in the immediate vicinity of the Shannon near Limerick.

Mr. Kilroe

The district next to be dealt with forms a belt six miles wide extending along the eastern side of the new map, from its southern margin northward to the boundary between County Limerick and County Tipperary, east of the Newport River, and thence to the Shannon about one mile south of Castleconnell. This tract was surveyed by Mr. J. R. Kilroe, whose report will now be followed.

The chief river in this tract is the Mulkear and its branches, which mainly descend from the hilly ground to the eastward of

r. Kilroe. . the map, though receiving tributaries also from the plain; and a smaller stream, the Groody River, drains a considerable portion of the low ground west of the basin of the Mulkear. The Carboniferous volcanic rocks stand out in the southern part of the tract as a bold ridge almost bare of drift, but elsewhere the solid rock is found at the surface only in comparatively limited and isolated hills and ridges. The superficial deposits covering the major part of the area consist of boulder-clay, which largely predominates; glacial sands and gravels, occurring both as eskers and as flat or slightly undulating tracts; and alluvium and peat along the river courses and in low-lying basins.

The boulder-clay, though mainly composed of limestone detritus, usually contains also a small admixture of material derived from the Old Red Sandstone and from the volcanic rocks of the district. Erratics of granite, like those met with in the areas previously described, also occur, but are exceedingly rare.

A well-marked difference is noticeable between the boulder-clay of the Mulkear Valley and that which borders the Shannon south of Castleconnell, the former containing a much larger proportion of clay than the latter. Indeed it was frequently difficult to decide whether the large drift-mounds in the neighbourhood of Thornfield, Lisnagry and Annacotty should be mapped as boulder-clay or as gravel. The clayey type of boulder-clay usually forms flat ground, and the uppermost portion, weathering freely, forms comparatively impervious soils and sub-soils.

The flat tracts of sand and gravel to the south of the Caherconlish hills are usually covered with a few feet of loam, and when this material is clayey and has a greater depth than about three feet it has been represented as boulder-clay on the map. It more nearly corresponds in character to the local boulder-clays, which clothe the flanks of the hills, than to the wide-spread limestone-boulder-clay of the plain.

Red clay, containing few stones, and these mostly of sandstone, rests upon the esker-sands at a few points, and may perhaps be explained as the product of occasional muddy flows across the ice-sheet from the neighbouring high ground of Old Red Sandstone during the later stages of the glaciation.

The glacial sand and gravels south of Ballyneety form an undulating and occasionally hummocky tract, with enclosed hollows or "kettle-holes," though in some places they assume a fairly level surface. Their stony contents are varied, but rounded fragments of limestone predominate. The manner in which these deposits are arranged in the vicinity of the hills suggests that they were deposited in temporary lakes impounded by an ice-barrier. This view is supported by the presence of two "dry gaps" or rocky gullies in the Caherconlish ridge, south of Inch, one of which shows glacial striæ nearly to its summit on the north side, while on the south side it presents evidence of strong erosion by water. These circumstances appear to indicate that there was a free escape for

the water on the south side, where a tract of flat-lying gravels has been deposited, while on the north side when the waters were impounded, no such conditions are noticeable. Mr. Kilro

Some curious structures, analogous to those mentioned in preceding reports, were observed in the gravels exposed in pits in the vicinity of the Caherconlish ridge. In one instance, an unstratified mass of coarse shingle was in part wrapped round by layers of sand and gravel which were buckled up and cut by small reverse-faults, evidently the result of lateral compression. Similar structures are also revealed in an esker which runs, with some interruptions, from Brittas west-north-westward to Sandville near Ballysimon. In a pit in this esker close to Bohergar Chapel, layers of fine sand 1½ to 2 inches in thickness, which alternate with gravel, have been forced into zigzags that are manifestly the result of overthrusting to the extent of some six inches. The lateral displacement indicated by these disturbances might be explained by supposing that a portion of the bank of ice, against which these stratified beds were deposited, moved inward upon the valley, containing the esker, at a time when the gravels were in a frozen condition.

The above-mentioned esker marks the course of the drainage before the ice-sheet had disappeared. The wide-spread accumulation of sand at Brittas, and the mounds which are elsewhere noticeable along the esker, taken in conjunction with the gaps that break its course in other places, appear to imply that special points of the bed of the ice-banked river were favourable for the accumulation of sediments, while in other places little or no material was deposited. The large tract of sand which occurs in the vicinity of Sandville seems to mark the delta of this esker-river, though other rivers of the same type, flowing southward parallel to the courses of the present Shannon and of the Killeennagariff, may have contributed to the accumulation. Evidence for the existence of the supposed esker-river on the ice-sheet of the Shannon Valley is forthcoming in the deposits of sand and gravel within the demesne of Mount Shannon and farther northward. There is also a conspicuous group of eskers to the south-east of Castleconnell, three miles to the eastward of the Shannon, which appears to be the prolongation of a similar deposit at the northern margin of the map, north-east of Castleconnell, and probably indicates an important drainage system flowing southward to a junction with the Brittas esker near Sandville.

The glacial striæ observed in the eastern part of the map are directed toward points between south and east. Thus, south of Caherconlish their direction is mainly somewhat to the east of south; near Brittas it is south-east; at Lisnagry, a little south of east.

Of the Post-glacial deposits, the most extensive are the alluvial sediments bordering the Mulkear and Annagh river-system and the Groody River. As the drift-covered ground adjacent to

Kilroe. the Groody River is very flat, the flood-waters have in the past spread over a wide area, depositing clayey or moory loam to a varying depth; and much of this alluvial land is still liable to floods. Narrow terraces of similar composition, higher than the general level, sometimes border these flats. Along the Mulkear and its tributaries, the margins of the flats are higher than the level reached by recent flood waters, but the embanking of the streams has considerably altered the original conditions. There have been several low-level peat-bogs in the area under description, but the greater part of these, where available for fuel, has been cut away. The original depth of the Lisnagry bog appears to have been about 24 feet, and that of Cappanahanagh, according to report, 18 to 20 feet.

Lamplugh. In the remaining tract, forming the north-eastern corner of the map, surveyed by Mr. G. W. Lamplugh, almost the whole of the ground is covered by superficial deposits, the "solid" rocks being exposed only here and there in the stream-cut valleys and in artificial excavations. This area includes the Stradbally bog, about three square miles in extent, lying partly in County Limerick and partly in Tipperary. This bog, which forms by far the largest tract of peat within the present map, occupies a basin partly surrounded by esker-like mounds of glacial sand and gravel, and partly by slopes of boulder-clay, overlying Carboniferous Limestone. This basin lies considerably above the level of the Shannon, the surface of the bog-land, where unbroken, being about 80 feet above that of the river; but near, and beyond, the northern edge of the map the bog has, in two places, spread westward over the rim of its basin and descends the slopes of boulder-clay, which intervene between it and the Shannon. Some further notes respecting this great mass of peat will be given subsequently.

In the vicinity of the Shannon the boulder-clay is derived principally from the waste of the Carboniferous Limestone, and is a dark, tough, stony clay. East of the Stradbally bog, however, it is modified by the incorporation of much detritus from the Old Red Sandstone, and is predominantly a red stony loam containing much sand. The best sections of this drift are revealed in the bluffs of the Newport River above Newport.

A huge pile of stratified drift, varying in texture from coarse bouldery gravel to fine yellow sand, fringes the western side of the Stradbally bog at the northern margin of the map and is continued southward as a broad steep-sided ridge for about a mile, where it drops suddenly below the level of the bog. At its higher northern end this ridge rises about 100 feet above the adjacent low ground to the westward. It appears to form a segment of a broken chain of similar moundy ridges that are seen at intervals skirting the eastern side of the Shannon for four or five miles from Birdhill southward. It is far steeper on the western side than on the eastern, and has in its higher portion a flat terrace-

like summit in places, this structure being repeated at successively lower levels when the ridge is followed southward. In these and some other features it differs somewhat from the normal type of esker. The majority of its boulders and pebbles are derived from the Old Red Sandstone with some Silurian slates and Carboniferous Limestone, but it likewise contains a very scanty sprinkling of far-travelled erratics, among which the Galway granite was recognised. Mr. Lamplugh.

A smaller ridge of sand and gravel juts out into the bog at a little over half a mile to the eastward of the main ridge, and evidently has its southward prolongation in three small detached mounds which rise as dry islands above the smooth wet expanse of peat about a quarter of a mile within the bog. Similar, though lower, moundy ground, composed of sand and gravel, emerges at the southern margin of the bog, one mile south-east of Castleconnell, and is continuous southward with the esker-belt already described by Mr. Kilroe.

It is clear that the bog lying within these drift-features has accumulated upon an uneven surface, the irregularities of which have been gradually overwhelmed by the thickening of the peat. It is noteworthy that the peat tends to rise higher on the slopes of sand and gravel than on those of boulder-clay, probably because the growth of the peat-forming vegetation is fostered by springs oozing from the gravels. Where the base of the peat has been reached in excavations, it is found to rest either upon gravel or upon stony clay, and not, as in many of the smaller basins farther southward, upon fresh-water marl. At present, however, it is only around its margin that the bottom of the bog has been reached, so that it is still possible that shell-marl, indicating the former existence of standing water, may be concealed under the deeper central portion of the tract. The turbaries in many cases show peat to a depth of 12 feet or more, while at least a further 8 feet is proved in some of the drains; but the 20 feet thus indicated is certainly not the maximum thickness of the accumulation.

The amount removed annually for fuel is very large, as it is used not only as the fuel-supply of the immediate neighbourhood but is also carted to Limerick.

It has already been mentioned that the bog appears to have formerly invaded the slopes to the westward; and in this connection it is worthy of note that four or five years ago great alarm was caused by the starting of a bog-flow at its north-western margin, just beyond the boundary of the present map. This flow was happily arrested by the embankment of the highroad to Killaloe; but, lacking this impediment, the flow might have continued to the low ground bordering the Shannon.

The wide stretch of alluvium to the south-east of the Stradbally bog, between the Newport and Annagh streams, lies well below the general level of the peat-bog. After their rapid descent from the Old Red Sandstone hills these streams have been checked

Lamp-gh. on reaching the Limestone plain and have thrown down their sediments, forming, where their valleys first expand, broad terraces of flood-gravel, which pass gradually outward into wide fans of silt and clayey loam. These sediments appear to have prevented the accumulation of peat within the area of their deposition, though a considerable amount of vegetable matter is incorporated with the finer silts and by its decomposition renders the water draining from these silts strongly ferruginous. In times of flood, the clearer waters, after the deposition of their burden of detritus, must have reached the bog-land basin and, by saturating it at intervals, conduced to the increase of peat. Under present conditions it is only where the surface of the bog has been artificially lowered by the cutting away of its margin that the peat-land is flooded, though a large extent of the lower alluvial flat would be frequently flooded were it not for the artificial embankments by which the rivers are now confined.

IV.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year :—

A. ENGLAND AND WALES.

I.—Maps.

One-inch Maps (New Series).

355 (Kingsbridge). *Additions.*

356 (Start Point). *Additions.*

The following maps previously issued hand-coloured, have been replaced by colour-printed maps :—

268 (Reading), Drift.
300 (Alresford), Drift.
315 (Southampton), Drift.
328 (Dorchester), Drift.
329 (Bournemouth), Drift.
342 (Weymouth and Portland), Drift.
343 (Swanage), Drift.

Six-inch Maps.

Leicestershire (with geological lines in colour.)

22 N.E. Measham (dated 1903). 22 N.W. Netherseal (dated 1903).

Index of Colours used in the Six-inch Maps of the North Staffordshire Coalfield. Price, Coloured, 1s. 6d. ; Uncoloured, 1s.

Six-inch Reference Maps.

Fifty-seven MS. coloured copies of six-inch quarter sheets have been made from the field copies and deposited in the office for public reference. These are as follows :—

Carmarthenshire.—47 N.E., S.E. ; 48 N.W., S.W.

Cheshire.—56 N.W., S.E.

Cornwall.—31 S.E. ; 32 N.W., S.W. ; 39 N.W., N.E., S.W., S.E. ; 40 N.W., S.W. ; 42 N.E. ; 43 N.W., S.W. ; 50 N.E., S.E. ; 51 N.W., N.E., S.W., S.E. ; 52 N.W., S.W. ; 56 N.W., S.W. ; 56A S.E.—61 N.E. and S.E. ; 61 S.W. ; 61A S.E. ; 62 S.W., S.E. ; 67 N.W., N.E., S.W., S.E. ; 68 N.W., N.E., S.W., S.E. ; 69 N.W., N.E. 73 N.W., N.E., S.W., S.E. ; 74 N.W., S.W. ; 78 N.W. ; 78 N.E. and S.E. ; 78 S.W. ; 79 N.W.

Derbyshire.—49 S.E. ; 50 S.W.

Staffordshire.—8 S.W.

II.—Vertical Sections.

Sheet 87. Sections of Shafts, etc., in the Coal Measures above the Hughes Vein near Neath, Swansea, and Llanelly. By A. Strahan and E. E. L. Dixon.

III.—MEMOIRS.

General Memoirs.

Summary of Progress of the Geological Survey of the United Kingdom for 1903, pp. 196. Price 1s.

The Cretaceous Rocks of Britain, Vol. III. The Upper Chalk of England By A. J. Jukes-Browne, with contributions by W. HILL. pp. 566 Price 10s.

District Memoirs.

Geology of the South Wales Coal Field, Part V. (the Country around Merthyr Tydvil). By A. STRAHAN, W. GIBSON, and T. C. CANTRILL. pp. 132. Price 1s. 6d. Part VI. (the Country around Bridgend). By A. STRAHAN and T. C. CANTRILL. With parts by H. B. WOODWARD and R. H. TIDDEMAN. pp. 120. Price 1s. 6d.

Water Supply of Lincolnshire from Underground Sources. By H. B. WOODWARD, W. WHITAKER, H. F. PARSONS, H. R. MILL, and H. PRESTON. pp. 229. Price 4s. 6d.

Sheet Memoirs.

Geology of the Oolitic and Cretaceous Rocks South of Scarborough. 2nd Edition. By C. FOX-STRANGWAYS, pp. 119. Price 4s. 6d.

Geology of the Country around Kingsbridge and Salcombe. By W. A. E. Ussher, pp. 82. Price 1s. 6d.

B. SCOTLAND.

1.—MAPS.

One-inch Maps.

Sheet 70 (West Central Skye with Soay).

Six-inch Reference Maps.

The following muanuscript copies of six-inch sheets have been made from the field copies and deposited in the office for public reference.

Argyllshire.—29, 30, 130.

Inverness-shire.—17, 133, 146.

Ross-shire.—97.

Edinburghshire.—3 N.W., N.E., S.W., S.E.; 4 N.W., N.E., S.W., S.E.; 6 S.E.; 7 N.W., N.E., S.W., S.E.; 8 N.E., S.W., S.E.; 13 N.W., S.W., S.E.; 14 N.W., N.E., S.W.; 18 N.E. (New Series).

Linlithgowshire.—3 S.W.; 6 N.E.

II.—VERTICAL SECTION.

Sheet 2a, illustrative of the Fifeshire Coalfield.

III.—MEMOIRS.

District Memoir.

The Tertiary Igneous Rocks of Skye. By A. HARKER, M.A., F.R.S., with notes by C. T. CLOUGH, M.A., pp. 481. Price 9s.

Sheet Memoir.

The Geology of West Central Skye with Soay (Sheet 70). By A. HARKER, M.A., F.R.S., and C. T. CLOUGH, M.A., pp. 59. Price 1s.

C.—IRELAND.

I.—MAPS.

One-inch Map.

Belfast (Drift Edition), colour-printed.

Six-inch Reference Maps.

The undermentioned Sheets have been copied from the field maps of the Drift Survey and deposited in the Dublin Office:

County Cork.—74, 75, 86, 87, with the surveyed portions of Sheets 62, 63, 64, 65, 73, 76, 85, 88, 97, 98, 99 and 100.

County Dublin.—9.

County Limerick.—1.

County Tipperary.—31 and 37.

II.—SHEET MEMOIR.

The Geology of the Country around Belfast. By G. W. LAMPLUGH, F.G.S., J. R. KILROE, A. McHENRY, H. J. SEYMOUR, W. B. WRIGHT, and H. B. MUFF, pp. 166. Price 3*s*.

LIST OF EXTRA OFFICIAL PUBLICATIONS.

BARROW, G.—The Moine Gneisses of the East Central Highlands and their Position in the Highland Sequence. *Quart. Journ. Geol. Soc.*, vol. ix., pp. 400–449, pls. xxxiii–xxxvii.

CANTRILL, T. C.—*Geology of Warwickshire* in Victoria County History. Folio. London.

CRAIG, E. H. CUNNINGHAM.—Metamorphism in the Loch Lomond District. *Quart. Journ Geol. Soc.*, vol. lx., pp. 10–29.

DIXON, E. and A. S. WOODWARD.—Report on the Long Excursion to the Ludlow District. *Proc. Geol. Assoc.*, vol. xviii., p. 487–491, pl. xlii.

FLETT, J. S.—Notes on the Collection of Rock-specimens made by Colonel English in European Turkey and Asia Minor. *Quart. Journ. Geol. Soc.*, vol. lx., pp. 276–277.

——— ———Note on the Microscopic Characters of the "Blood Rain" that fell over the South of England on February 22, 1903. (Appendix to the Great Dust-fall of February, 1903, and its Origin, by H. R. MILL and R. G. K. LEMPFERT.) *Quart. Journ. Roy. Meteor. Soc.*, vol. xxx., p. 73.

——— ———Report on the Rock Specimens and some of the Oozes Collected by the ss. "Faraday" and ss. "Minia" from the Bed of the North Atlantic in 1903. Recent Contributions to our Knowledge of the Floor of the North Atlantic Ocean, by SIR J. MURRAY and R. E. PEAKE, pp. 23–27. *R. Geogr. Soc. Lond.*

GOODCHILD, J. G.—The Geological History of Lower Tweedside. *Proc. Geol. Assoc.* vol. xviii., pp. 105–142.

——— ———Report on the Excursions to the Coast North and South of Berwick-on-Tweed, Cockburn Law, The Cheviots, and the Eildon Hills. *Ibid.* pp. 307–321.

———————Reports on the Excursions to Cockburnspath and Peebles. *Proc. Berwickshire Nat. Club.*, vol. xix. pp. 223–258.

GOODCHILD, J. G.—Some Field Evidence Relating to the Mode of Occurrence of Intrusive Rocks. *Proc. Roy. Soc. Edin.*, vol. xxv., pt. iii., pp. 197–226.

————————The Older Deutozoic Rocks of North Britain. *Geol. Mag.* pp. 591–602.

————————The Natural History of Scottish Zeolites. *Trans. Geol. Soc. Glasgow*, vol. xii., Supplement, pp. 1–68.

KITCHIN, F. L.—Obituary Notice: Geheimrath Prof. K. A. von Zittel. *Geol. Mag.*, 1904, p. 90, pl. iv.

LAMPLUGH, G. W.—Cretaceous Phosphatic-beds and their Fauna. *Geol. Mag.*, 1904, p. 551 (*Rep. British Assoc.* for 1904, p. 548.)

MACALISTER, D. A.—A Cross-section and some Notes on the Tin and Copper Deposits of Camborne. *Tr. Roy. Geol. Soc. Corn.*, vol. xii., pp. 771–795.

NEWTON, E. T.—Notes on the Triassic Fossils (excluding Rhætic) in the Museum of the Geological Survey at Jermyn Street, London (Report on the Fauna and Flora of the Trias of the British Isles.) *Rep. Brit. Assoc.* for 1904, pp. 282–285.

———————————The Occurrence of *Edestus* in the Coal-Measures of Britain. *Quart. Journ. Geol. Soc.*, vol. lx., pp. 1–8, pl. i.

PEACH, B. N., and J. HORNE.—Notes on the Geology of the Assynt District with Geological Map. *Scottish Geog. Mag.*, May, vol. xx., pp. 235–245.

———————————Notes on the Geology of the Loch Maree District with Geological Map. *Scottish Geogr. Mag.*, Dec., vol. xx., pp. 634–640, also *Geogr. Journ.*, Nov., vol. xxiv., pp. 569–574.

REID, C.—The Probable Occurrence of an Eocene Outlier off the Cornish Coast. *Quart. Journ. Geol. Soc.*, vol. lx., pp. 113–119.

————————Notes on the Plants from Roman Silchester, in Report on the Excavations. *Archæologia*, vol. lix.

————————Note on the Plants (Report on the Drift Deposits at Kirmington, Lincolnshire. *Geol. Mag.* 1904, p. 512. (*Rep. Brit. Assoc.* for 1904, p. 272–274.)

————————*Najas marina* in the *Megaceros-marl* of Lough Gur. *Irish Naturalist*, vol. xiii., p. 162.

————————and E. M. REID—A Probable Palæolithic Floor at Prah Sands (Cornwall). *Quart. Journ. Geol. Soc.*, vol. lx., pp. 106–112.

STRAHAN, A.—Presidential Address to the Geological Section of the British Association. *Geol. Mag.*, p. 449. (*Rep. Brit. Assoc.* for 1904, p. 532–541.)

USSHER, W. A. E.—The Devonian Rocks of Cornwall. *Geol. Mag.*, pp. 587–591.

WOODWARD, H. B.—Note on a Small Anticline in the Great Oolite Series at Clapham, north of Bedford. (*Brit. Assoc.*) *Geol. Mag.*, pp. 439–441.

————————Excursion to Upminster, Great Warley, and Brentwood. *Proc. Geol. Assoc.*, vol. xviii., pp. 479–486.

————————A Memoir of Robert Etheridge. *Proc. Bristol Nat. Soc.*, vol. x. (N.S.), pp. 175–187.

WRIGHT, W. B., and H. B. MUFF.—The Pre-glacial Raised Beach of the South Coast of Ireland. *Sci. Proc. Roy. Dublin Soc.*, vol. x. (N.S.), p. 250.

APPENDIX.

I.—The Search for Coal Beneath the Red Rocks of the Midland Counties.*

BY WALCOT GIBSON, B.SC., F.G.S.

Introduction.—Since the memorable and successful sinking to reach coal at Sandwell Park on the east side of the eastern boundary fault of the South Staffordshire Coalfield, several attempts, some successful and some not, have been made over wide areas in the Midlands. The breaking of new ground at Sandwell in 1870 was due to the prospect of the exhaustion, in the near future, of the Thick Coal within the exposed coalfield. To the late Henry Johnson of Dudley belongs the credit of what was then a bold undertaking, and he is justly regarded as the pioneer in these important explorations. This first and successful attempt to prove the existence of the Thick Coal outside the visible coalfield has led many to believe that workable seams exist anywhere in the neighbourhood of the exposed coalfield; whereas there is always an element of uncertainty if productive measures will be reached by boring through the Red Rocks, owing to the very irregular floor on which the Coal-measures were deposited, or to their subsequent denudation before the Red Rocks were laid down.

The necessity for extending the area of the Midland coalfields beyond their exposed limits still remains, and around each of them large quantities of coal are being drawn from beneath the newer rocks; while fresh explorations are daily taking place and others are in contemplation. It is felt that this is a matter in which the geologist can materially assist the explorer, and that he should stand in relation to the mining engineer much as the astronomer does to the traveller, by affording him the data on which to fix his position in unknown ground. A book containing an account of borings and shaft-sinkings with the depth and exact description of the strata would be as useful to the mining engineer as the Nautical Almanac is to the navigator or traveller. Several of the Survey publications contain such records; but a volume entirely devoted to the records of shaft-sinkings and borings would possess as much value in coal-mining as those of well-sections, now under publication, possess in questions of water-supply.

It is the object here to give some of the more important results obtained from the examination of several borings in the Midlands either still in progress or but recently completed. At the same time we propose to offer some preliminary remarks bearing on the subject, which, though known to geologists, are not, we think, universally taken into account by mining engineers.

* For a report on the Eastern Counties, by Prof. P. F. Kendall, see *Rep. Roy. Commission on Coal Supplies*, Part IX., 1905.

THE PRE-CARBONIFEROUS FLOOR.

The character and irregular nature of the surface upon which the carboniferous rocks were deposited has been clearly described by Professor Lapworth.*

" The ranges of Charnwood and the Malverns, of the Wrekin and the Longmynd, etc., were apparently already in existence, or had been blocked out in outline. But while our present evidences suggest that the more elevated parts of the rocky floor of the irregular basin in which the Carboniferous strata of the Midlands were deposited lay along the south and south-eastern parts of the Midland District, it has long been known that the deeper part of the basin and those to become first submerged lay to the north and north-west, along a line ranging from Coalbrookdale down the valley of the Trent in the direction of the Humber."

It thus happens that rocks older than Coal-measures are at or are nearer the surface in the southern than in the northern portions of the Midland district.

INTER-CARBONIFEROUS MOVEMENTS.

The most reasonable explanation of the great thickness and great variation in thickness of the Carboniferous rocks, together with the repeated occurrence of coal seams, is, that movement has taken place during their deposition. These movements we consider to have been of a very gentle character; and, though varying in intensity from place to place, to have never resulted in acute folds. They are essentially of a local and not of a regional character. Since, as is generally accepted, the whole of the Carboniferous rocks accumulated in shallow water, one of the effects of these movements would be that an area slowly rising would soon lie beyond the limit of deposition, and would thus be exposed for a time at the surface; while a closely contiguous area, undergoing depression, would receive an access of sediment. It is in this way that the " wash-outs," caused by denudation above base-level, may be accounted for. The extent of the " wash-out " would primarily depend on the time the beds lay above water, and can only be determined by mining. The so-called " Symon Fault " of the Coalbrookdale Coalfield would appear to represent an unusually long lapse of time. Excepting in this instance, where, it should be remembered, we are dealing with the gently rising western margin of the great inland coal basin, the elevation of any one tract never lasted a sufficient length of time for denudation to remove a large quantity of material. Over the great depressions we should not expect that wash-outs would occur, at any rate not on a large scale, and indeed this condition is found to obtain within the exposed coalfields, and may therefore be expected to hold good in the concealed areas.

Proc. Geol. Assoc. Vol. xv., 1898, p. 363; see also *Rep. Roy. Commission on Coal Supplies*, Part III., 1905.

POST-CARBONIFEROUS AND PRE-TRIASSIC MOVEMENTS.

These are the most powerful and most important of all. Their main features have been recently described by Mr. A. Strahan in his presidential address before the British Association (Cambridge Meeting, 1904). The chief point for consideration here is that at this period the great synclines and anticlines, accompanied at the same time by powerful fracturing of the rocks, originated and were completed. In some instances these disturbances took place along the lines determined by those of inter-Carboniferous age. This is certainly the case in North Staffordshire, where over what is known as the "Staffordshire Anticline," which is mainly of post-Carboniferous but pre-triassic age, the Coal-measures are exceptionally thin, and therefore, as we have already stated, this area was probably undergoing elevation in Carboniferous times. We may therefore infer that over the area in the line of the continuation of this anticline to the south-west between Madeley and Mucklestone, the Coal-measures in these unproved regions will also be found to be comparatively thin (*see* however, p. 148). As a whole, however, the post-carboniferous movements tend to disguise the lesser ones of Carboniferous age.

PRE-TRIASSIC DENUDATION.

This was greatest over and along the margins of the anticlinal uplifts, and thus diminishes the relative heights of the saddles and troughs formed by the post-Carboniferous disturbances. This denudation, which was on a vast scale, prepared the surface on which the Triassic rocks were deposited. Beyond this very general statement we possess no means of determining the amount of denudation at any one spot. It is, therefore, always uncertain what portion of the Carboniferous rocks will be met with under their "Red Rock" cover. Towards the centre of the major synclines we may reasonably expect the full sequence of Coal-measures, and less and less of this sequence as the margins of the basins are approached.

TRIASSIC DEPOSITION.

Possibly few results obtained by recent borings are more startling than the proof of the rapid thickening of the Triassic rocks within short distances of the margins of the coal-fields. The Trias has evidently been deposited in steep-sided valleys of erosion in the Carboniferous or older rocks. One fact is clear, the Trias is everywhere thickest towards the centres of the great synclines, though the prevalent attenuation in a general south-easterly direction, long ago determined by Professor Hull, has been found to hold good. Another factor is equally clear. The Keuper Marls and sandstones rapidly overlap the Bunter. A striking instance of this has been met with in a boring at Lullington, west of Netherseal. Judging from surface outcrops the thickness of Keuper

sandstones and marls should here have been comparatively small, whereas, owing to overlap, the Keuper rocks are several hundred feet thick.

POST-TRIASSIC MOVEMENTS.

That these movements followed along the same lines, or on approximately the same lines, as those of pre-triassic age has been proved in many areas. The main fractures therefore serve as guides to the existence of still greater faults in the Coal-measures. It must, however, be remembered that the large amount of throw assigned to some of the post-triassic faults can be frequently explained by the Triassic rocks having been deposited in steep-sided valleys eroded in the older rocks.

THE COAL-MEASURE SEQUENCE.

The geological considerations in selecting a site for a boring beneath the Trias must be necessarily governed by the fore-mentioned factors. The question now arises, have we any data to forecast the probable thickness of barren coal-measures to be passed through before workable seams are reached, and by what characters can these barren measures be distinguished from the rest of the Carboniferous sequence. The question of tapping rocks older than the Coal-measures need not be discussed. It is sufficient to say that within the great synclines, after making allowances for post-carboniferous denudation which we believe was not extensive over the depressed areas, there is every reason to expect that the Productive measures exist. On the other hand, over the anticlinal regions—such as in the ground near Mucklestone (p. 147) and along the margins of the Midland Basin—there is always the possibility of the occurrence of rocks older than the Coal-measures.

We shall consider the sequence from the stand point of deep-winnings only. For this purpose a threefold division can be adopted, as follows :—

1. Upper Unproductive Series.
2. Middle Productive Series.
3. Lower Unproductive Series.

The upper Series is thickest (over 2700 feet) in the northern region of the great syncline between the Welsh hills and those of Lancashire and North Staffordshire ; it is thinner (about 1800 feet) near the southern end of this basin between South Staffordshire and Shropshire ; it is thinnest (800 feet) to the east of the Nottinghamshire and Derbyshire coalfields. Between South Staffordshire and Warwickshire the thickness is uncertain, as much doubt exists whether certain red beds are of Triassic or of earlier date. At Sandwell Park the thickness appears to be over 1000 feet. The conclusions of Professor Hull that the thickness of these upper measures would prove to be the great drawback in sinking for coal around the margins of the exposed coalfields has been found to be correct.

It is not necessary to give the varying thickness of the Middle and Lower Series, as this is well known for the respective coalfields.

The upper series has recently been studied in more detail than was possible some years ago, and an apparently well-established succession has been made out, of which the coalfield of North Staffordshire affords the type. Since this sequence has been met with over wide areas and forms one of the important factors with which we are here concerned, we propose to give their main characteristics in sufficient detail to enable them to be recognised. The nomenclature established in North Staffordshire will be used.

UPPER UNPRODUCTIVE SERIES.

	Thickness in Feet (Maximum).			
	Denbigh.	N. Staffs.	S. Staffs.	Notts.
Keele Group - - - - - -	800+	800+	850+	200+
Newcastle-under-Lyme Group -	400	400	360	100
Etruria Marl Group - - -	1100	1100	300	300
Black Band Group - - - -	—	450	—	200

Keele Group.—As fresh borings pierce these rocks our information increases, though it is still scanty enough. It is open to doubt how much of the upper part of the Enville and South Staffordshire succession belongs to this group, and how much classified as Permian in Warwickshire should in reality be placed in the Trias. The group consists of red sandstones and marls. There is an occasional band of Spirorbis limestone, one of which appears to occupy a definite position along the southern margin of the basin—Arley, Claverley, Sandwell. Plants: *Neuropteris Scheuchzeri, N. heterophylla* (Claverley), *Pecopteris arborescens* var. *cyathea, P. Miltoni*. Molluscan remains, none. Fish remains, none. Equivalents—Lower Permian Rocks of the central Midlands.

Newcastle-under-Lyme Group.—Grey sandstones and shales with thin coal seams. Spirorbis limestone, at irregular intervals. Plants same as in Keele Group, but with many others; Mollusca, *Anthracomya calcifera* in limestones and associated shales; Fishes, *Cœlacanthus, Acanthodes*. Equivalents—Coedyrallt Rocks of Denbighshire. Halesowen Sandstone Group of South Staffordshire, Sulphur Coal Group of the Forest of Wyre.

Etruria Marl Group.—Essentially red and mottled clays, green rocks (Espley rocks) in bands, recognisable in hand specimens and consisting largely of derived volcanic material. The "Espleys" are coarse angular breccias in the proximity of pre-carboniferous rocks and fine-grained grits in the deeper parts of the troughs. Spirorbis limestones at intervals. Equivalents—Ruabon Red Marls? Upper part of Ardwick Series? Calamincar rocks of Coalbrookdale, Red Clays of South Staffordshire. Recognised but not named in Warwickshire and Nottinghamshire.

Black Band Group.—Grey measures with thin seams of coal. Blackband ironstones and Spirorbis limestones in the north. Plants numerous and the same as in the Newcastle-under-Lyme Group. Mollusca, *Anthracomya Phillipsi*, very abundant. Equivalents—Lower part of Ardwick Series and the top portion of the Middle Productive Series of the remaining Coalfields.

The relation of the groups to each other and to the underlying Productive Series is one of perfect conformity. Around the southern margin of the basin the different members overlap each other and finally (Lickey Hills) rest on rocks older than the Coal-measures. The western margin of the basin has not been examined in detail, but overlap takes place in the neighbourhood of Bridgnorth.

The four sub-divisions, excepting perhaps that of the Black Band Group in the southern region, can with ordinary care be recognised. The question next arises as to what are the differences, lithological and palæontological, separating the Upper Series from beds lower down in the Carboniferous sequence. This becomes of importance near the margins of the exposed coalfields where, as we have seen, uncertainty exists as to what portion of the carboniferous sequence may be met with below the Trias.

Red sandstones and red marls, lithologically resembling those of the Keele and Etruria Marl Groups, occur on several horizons in the sequence above the Carboniferous Limestone. Have we, then, any means of telling whether a boring, commencing in unproved ground, and meeting with red Carboniferous rocks, has reached an horizon high up in the Coal measures or one wholly below the Productive Series.

Taking the palæontological evidence, *Anthracomya Phillipsi* and *Pecopteris arborescens* have only been met with high up in the Coal-measure sequence. On the other hand, certain well-defined species of *Carbonicola*, *Anthracomya*, and *Naiadites* characterise the Productive Series and have never been found on higher or lower horizons in the Midlands. Among the plants *Alethopteris lonchitica* is common in the Middle and Lower Series, but is rare in the upper Series. No fauna, essentially marine, occurs in the Upper Series. On the other hand marine horizons are frequent in the Productive measures; but excepting in North Staffordshire have not been found to contain a fauna markedly distinct from that met with in the rocks older than the Coal-measures, but newer than the Carboniferous Limestone.

We will now give instances of recent borings where this information has been or could have been applied.

Claverley.—This boring, situated one and a half miles south-east of the village of Claverley (five miles east of Bridgnorth), is in progress. For permission to examine the cores and to publish these remarks our thanks are due to Mr. Edward Parry, to whom the credit belongs of making this bold attempt to prove new ground in an area remote from any workings. The boring commenced

in the Upper Permian of Mr. Wickham King * and at a depth of 488 feet entered red beds of a distinctly Keele type. A dark limestone with Spirorbis was passed through at a depth of 991 feet. This position agrees with the band described by Mr. Cantrill in the neighbourhood of Upper Arley and not unlikely to be on about the same horizon as the well-known band at Sandwell Park.† Beneath this a bed contained numerous plant remains, of which Mr. R. Kidston has identified the following species: — *Annularia sphenophylloides* (Zenker); *Cordaites borassifolius* (Sternberg); *Calamites*, sp.: *Lepidodendron*, sp.; *Neuropteris ovata* (Hoffman), *N. heterophylla* (Brongniart), *N. Scheuchzeri* (Hoffman), *Pecopteris cyathea* (Brongniart.) There was an entire absence of mollusca and fish remains. The lithological characters and palæontological contents indicate that the beds are the equivalents of the Keele Group. As the measures are lying horizontally and are situated towards the centre of the syncline the underlying groups of the upper series should occur here. Subsequent boring proved this to be correct.

Desford.—This boring is situated six miles south-west of the Town of Leicester and therefore lies towards the south-eastern margin of the Midland basin. It commenced in Trias and at 372 feet entered red rocks which, though lithologically similar to those of the Keele Group, were found on examination of the cores to contain *Lingula* in fair abundance and scales of *Rhizodopsis*, a genus of Fishes not met with higher than the Black Band Group. We are therefore not dealing with the Keele Group but with some lower part of the sequence. The absence of the mollusca characteristic of the Productive Series indicates that these red beds belong to some place even still lower in the sequence. As a matter of fact the Millstone Grit was entered at a depth of 461 feet; the Carboniferous Limestone at 472 feet depth; and the pre-Carboniferous floor at 500 feet depth.

Manchester.‡—Some borings situated in the neighbourhood of Manchester commence in Drift, and after passing through the Triassic and Permian formations enter some red beds closely resembling those of the Keele Group. Beneath these come a grey group of rocks and below these ordinary grey coal measures with seams of coal. As the measures are lying at a gentle angle and the borings are situated somewhat towards the centre of the Lancashire coal-basin, we might have expected that these red beds would have proved to be the equivalent of the Keele Group. In this case we should have looked for some representative of the Newcastle-under-Lyme and Etruria Marl Groups with the green Espley rocks in the latter, unless they had been cut out by faulting. On breaking up the cores of the red beds, *Anthracomya Phillipsi* was found to be abundant. This indicated an horizon not higher than the Black

* *Quart. Journ. Geol. Soc.* Vol. lv., 1899, p. 97. † *Ibid.*, Vol. li., 1895, p. 534.

‡ For permission to examine the cores from the Astley boring we are indebted to Mr. W. Fairclough.

Band Group of North Staffordshire, and to this position we are inclined to assign them.

These three examples show the value of palæontological evidence in fixing horizons among the Carboniferous sequence. Among other instances known to us are: Thurgarton Boring (Notts), Newstead and Keele borings (N. Staffordshire), Sandwell Park (S. Stafford), all situated towards the centres of large basins and in all of which the Upper Series can be distinguished by lithological and palæontological characters; and beneath which the Middle Series has been proved to exist.

General Remarks.

Having examined a large number of borings put down in search for coal in the Midlands, we now propose to give a few general remarks which it is hoped will be of service to those contemplating further explorations.

Size of Holes.—It may be affirmed that cores under two inches in diameter are seldom of much value in determining the precise horizon of the rock passed through. Yet it is comparatively rare to find that cores of Coal-measure ground exceed this diameter at depths over 2,000 feet. The mistake has almost universally lain in commencing with a hole too small in diameter, especially where a great thickness of Coal-measures has to be penetrated. Under any method of drilling, the Coal-measure strata present many difficulties. The great thickness of marls at so many horizons necessitates repeated casings and consequent diminution of the diameter of the core. Another common obstacle is the occurrence of small nodules of ironstone in the shales and marls. Unless the hole is cased these slip down to the bottom of the hole and tend to considerably reduce the diameter of the core by wearing it away during the rotation of the drill, besides causing extensive caving in of the hole. If a boring of which the major portion will be in Coal-measures is intended to give a core of any value at a depth exceeding 2,000 feet, the diameter at commencement should not be under 15 inches in diameter.

Records and preservation of cores.—It is generally acknowledged that records of sinkings and borings have, in many instances in the past, been imperfectly kept. The unintelligible terminology of the sinker, whose main object is rapidity of boring or sinking, has been usually adopted and the strata passed through incorrectly described. Nor has there, up to the present, been much improvement in this respect, except in a few instances. In the case of a boring or shaft going through unproved ground, it would be of great value if complete samples of each kind of rock, correctly named and with the technical and local terminology attached, as well as any fossils collected, were preserved for reference in some local institution, easy of access to anyone wishing to consult them.

Cores, too, are often badly preserved. We have met with them stored in old lofts, dust covered and in motley confusion, or arranged in the open in fields. It is seldom they are placed in boxes, and then, as the cores get smaller, several lengths are frequently piled one on the top of the other without dividing partitions. A few instances we can recall, and a few only, where the cores have been laid in lengths in a shed sufficiently large to accommodate the entire cores in separate rows. So long as the engineer is sure of his ground it does not much matter, from his point of view; but where, as daily becomes of more common occurrence, the ground is uncertain and an expert is called in at a late stage, the value of the boring is often impaired or even entirely thrown away, owing to the imperfect way in which the cores have been kept.

II. Notes on Ore-Dressing in Cornwall.

BY DONALD A. MACALISTER, ASSOC.R.S.M., F.G.S.

The present price of both tin and wolfram is so high that it is probable some of the abandoned mines could be profitably worked by modern methods. In the early days the lodes were frequently wrought for only one of the metalliferous minerals contained in them, while the others were thrown to waste or not "mined" at all. As a consequence some of the old heaps of 'sands' or tailings from former dressing operations, as well as some of the mine "burrows" or "tips," contain mineral which might yet be extracted. This is especially true in the cases where the refuse was originally a mixed ore but treated only for copper or arsenic. The Gunnislake Clitters Company, for instance, crushed and dressed quite recently a heap of 'burnt leavings' which had originally been treated solely for the arsenic it contained. The tin and wolfram contained in this heap—known as the Greenhill Burrow—was extracted at small cost and yielded considerable profits. A great deal of attention is now given to the whole question of dressing at several of the mines, and the results from various quarters show what is being done with low grade ores by the careful treatment of a large quantity of stuff passed rapidly through the stamps.

The tin ore from the Cornish Mines generally contains over 1 per cent. of cassiterite; it can be made to cover the costs of mining and dressing if it contains only a little under 1 per cent. (22·4 lbs. per ton). The ore after beirg dressed is known on the market as "Black-tin." This product generally contains over 90 per cent. of cassiterite. Black-tin yields by smelting about 65 per cent. of metallic tin.

The stamps usually employed in the newer plants are the *Californian*, the heads of which weigh from 800 to 1,200 lbs. apiece and deal about eighty blows a minute. Each stamp crushes from two to three tons of ore a day to a size small enough to pass a twenty-five mesh wire grating. The old *Cornish* stamps are still used in many mines. The head varies in weight, but 700 lbs. is a

common size, while the number of blows dealt is about sixty-five a minute. The distance the stamp falls through before delivering the blow varies up to about nine inches. In some mines the stamps have no dies but beat their own bed on the bare ground. For this purpose the stamps after being rigged up are set going for a few weeks crushing hard barren material until the ground so prepared is tough enough to take the ore.

In crushing, the ore must be reduced to a "pulp" sufficiently fine to liberate the particles of metalliferous minerals from the veinstone; but if it is too fine, an unnecessary amount of "slime," and consequent loss, is the result. Each blow of the stamp splashes some pulp against the wire screens (gratings) or the perforated plates placed in front of the mortar-box. Wire gratings are more efficacious than perforated plates, but they require to be renewed more frequently. In the case of perforated plates the width of metal between the holes prevents the pulp from passing freely through, so that it falls back and is stamped to an unnecessary degree of fineness. Twenty or twenty-five mesh wire gratings (400 or 625 holes per square inch) are used in some of the mines.

Frue vanners are used for treating pulp from the stamps. In these machines the pulp is distributed on a broad endless belt which travels continuously (supported by rollers) from one end of the machine to the other. At the "feed" end, towards which the belt travels, the upper part of the belt is slightly more elevated than at the other end. A sideways oscillating movement is communicated to the belt by means of an eccentric at the side of the machine. The pulp is distributed in a stream near the end to which the upper part of the belt is travelling. The lighter particles of veinstone and the fine slimes are carried over the belt by a flow of water (provided by a series of jets) in the opposite direction to that in which the belt travels. The coarser, heavier mineral grains, on the contrary, cling to the surface of the belt and are carried forward against the current of water and so pass over the end and are washed off in a trough situated below the belt. The action is simply this. The large veinstone fragments present a large surface to the current of water and so are urged backward with the current. The very fine material whether of high specific gravity or not remains suspended or buoyed up in the water for a considerable time and so is also carried backward with the stream. It is in this finest material (slime) that cassiterite in a fine state of division may and does escape. The heaviest material sinks rapidly, and its weight enables it to be carried along on the belt against the current. The lateral oscillations of the vanner assist the separation of cassiterite and veinstone, but as a whole, the balance of the effects of the current of water and the force with which the particles cling to the belt is generally slightly in favour of the latter so that some other minerals (such as tourmaline, etc., except when in a very fine state of division) pass over with cassiterite.

It is claimed that these machines work efficiently with but little water and are able to treat unsized pulp. The layer of grains in fairly thick pulp is supposed to prevent the slime tin from being carried away in the water and to allow it to settle on the belt with the coarser mineral grains. A Frue vanner can treat from five to ten tons of stuff daily.

Luhrig vanners are generally employed for slimes. In appearance the machine is similar to the Frue vanner, but its action is different. In the Luhrig vanner the travelling belt is not subjected to an oscillating movement; and instead of sloping from one end of the machine to the other, the slope is in a lateral direction; that is to say, at right angles to the direction in which the belt travels.

The slime is fed on the table at the end from which the belt travels, and a continuous current of water is supplied from sprays in a pipe set along the diagonal of the belt which extends from the upper edge of the belt near the feed to the lower end at the opposite corner. The light veinstone is washed off continuously by the spray, so that by the time the stuff has reached the other end of the machine practically nothing remains but "black tin" which is readily washed off as it comes under the direct influence of the spray.

Shaking or bumping tables are a class of concentrators of the well-known Rittinger type. Those used in Cornwall are the "*Wilfley*" and the "*Buss*" tables, which are only modifications of the Rittinger. Their action is very similar. The table is rectangular and slightly inclined in a direction at right angles to its length. An oscillating movement is communicated to the table by means of an eccentric. A number of strips of wood (riffles) of varying length are nailed, an inch or so apart, on the table, from the short edge at the feed end, parallel to its longer edges. The longest strips are near the lower edge of the table and the shorter near the "feed" or upper edge. The object of these strips is to interfere with the down flowing pulp and so prevent the current from having a greater influence than the effect of the shock. The pulp is fed on at one end of the long upper edge of the table. The heavier particles traverse the table diagonally near the ends of the riffles, being carried forward by the influence of the shock imparted to them by the table and downwards by a current of clean water issuing from sprays in a pipe extending along the upper edge of the table. The action appears to be this. The current of water washes the material down in the direction of its flow. The very light or flaky minerals together with those in a very fine state of division are buoyed up and carried over the riffles to the lower edge of the table and flow away to waste or are treated in another way. The heavy metalliferous grains together with large particles of veinstone materials (which although presenting a large surface in proportion to their density are too heavy to pass over the riffles) are urged forward in the direction in which the table is oscillating. The result is that under the combined influence of the force exerted on the partic[illegible] by the water, and the force with which the minerals are u[illegible]

forward in the direction in which the table is oscillating, both the heavy metalliferous particles and the larger veinstone materials travel down the table diagonally.

Sufficient water is allowed on the table to keep the particles free and clean. The minerals arrange themselves roughly in order of density. The cassiterite is urged forward by the oscillations of the table and is not carried down the table so rapidly as in the case of the coarser but lighter minerals. The result is that the two streams of minerals gradually separate and are caught in separate troughs (launders) at the foot of the table. In practice it is obvious that the best results are obtained when the materials are classified in upward current separators before being passed on to the tables.

At Polmear Mine (Charlestown, St. Austell), Mr. J. F. C. Abelspies, F.G.S. has carried out a series of experiments with the object of improving upon the usual processes for first treatment of the pulp from the stamps. These experiments have resulted in the production of a table of the Rittinger type but modified in such a way that the ore is roughly classified (without additional water) at the upper end of the table, near the feed, before passing over the riffles. By this classification three grades of materials are obtained which flow into three separate segments of the table having similar arrangements of longitudinal riffles. A special feature is that from the end of each set of riffles there is a strip placed at 45° to them which extends to the lower edge of the table and in the direction in which the particles move. When the table is oscillating, these strips by interfering with the downflowing pulp produce a vanning action. In this manner the finest heavy mineral particles are thrown furthest away from the gangue and even in front of the coarse heavy mineral grains.

Revolving frames or tables are used in the later stages of tin dressing but there are many modifications of them. They all consist of a circular revolving deck of the shape of a shallow convex or concave cone. Some are double-decked. In the concave table a fixed distributing arrangement feeds the slime on to the outer circumference continuously at one segment. The stream at once commences to flow inwards—the heavier particles lagging behind the lighter. As the table revolves the deposit comes under the influence of a gentle stream of clean water which washes away the barren vein material from among the metalliferous particles. When the table has nearly completed a revolution, all that is left on any particular segment is a rich concentrate which is readily washed off by a powerful spray into a separate launder. The arrangement is automatic and continuous. In the double-decked tables the tables are placed concentrically, revolving in the same direction on the same axis. The concentrates are washed off the outer deck at certain points, but the "tails" flow on to the second deck and are treated in a similar manner. The *Acme table* is a new modification of the double-deck table. The

decks are placed concentrically but the outer one is concave while the inner one is convex. The tails from the outer deck are led into a launder (trough) and lifted up by a raft wheel (bucket wheel) and delivered on to the inner table which is supposed to extract the cassiterite which has escaped in the tails from the outer deck.

Buddles are concentrating arrangements used in the later stages of tin-ore dressing. A buddle consists of a circular fixed bed which slopes downwards from the circumference to the centre (concave buddle) or from the centre to the circumference (convex buddle). In the convex buddle the ore is distributed at the head or centre of the bed. In concave buddles, the ore is distributed at the circumference by means of radial trough shaped arms which revolve round a vertical axis at the centre of the bed. In both cases light brushes suspended from arms sweep over the surface to keep the deposit even.

In the convex buddle the velocity and volume of the stream flowing over any unit area is greatest at the head of the buddle. That is to say, it is greatest at the points where the ore is being fed on and where the heavy mineral particles settle, and least at the places on which the lighter material settles.

With concave buddles the reverse is the case, *i.e.*, the velocity and volume of the stream is least at the circumference, where the heavy minerals are deposited, and greatest at the "tail" where the lighter minerals collect. The deposit is not washed off as in the case of the revolving tables, but is allowed to accumulate until it is about a foot thick. The machine is then stopped and the various grades of stuff, arranged in concentric annular deposits, are dug out and separately handled according to the quality.

A rough classification is made at a certain stage of dressing by means of a small buddle called a "*Dumb pit.*" The arrangement is of the simplest kind with none of the adjuncts of the ordinary buddle. The ore pours into the middle of the bed in a thick stream. The heavier minerals remain near the middle while the lighter are washed to the circumference. As soon as a sufficient thickness is deposited, the materials are dug out and separately handled according to quality.

The last operation in the dressing of tin-ore takes place in *kieves* (or large tubs). Dressed tin-ore already highly concentrated is stirred up in the kieve with plenty of water. It is then allowed to settle while the tub is tapped repeatedly by a hammer on the outside. The effect of this is to make the lighter stuff come to the surface while the richest stuff remains at the bottom of the tub. The deposit is skimmed and is then ready for the market.

The tailings from the treatment of tin slimes are worked over again on plane tables (or *Ragging Frames*). Each ragging frame consists of a fixed rectangular sloping frame over which the slime is distributed from a trough (or launder) which feeds a series of these frames. The heavy particles remain on the surface

while the lighter waste flows off into a launder. After a minute or so there is a small quantity of concentrate settled on the table, and this is washed off by a cascade of water which is dashed over the surface from a trough which topples over automatically when it is full of water. At the same time an arrangement at the foot of the table, actuated by a lever connected with the toppling-trough, directs the concentrate into a special launder. The ragging frames are chiefly used in the stream works for taking out the cassiterite from slimes which flow to waste from the dressing floors at the various mines.

Wetherell electro-magnetic separators (Messrs. Humboldt, Cologne), are now being used for the extraction of wolfram at several of the mines. These machines are installed at East Pool Mine (Camborne), the Bunny Mine (St. Austell), and at Gunnislake Clitters Mine (Calstock). The separation of wolfram and tin is best accomplished by these machines. Their economic importance is shown in a practical way in the statistics relating to the output of wolfram in the Blue-books issued by the Home Office (*e.g.* year 1903).

Partially dressed ore from the calciner, containing both tin and wolfram, has, among ordinary veinstone impurities, a certain amount of " iron " which is extracted before separating the wolfram and tin. The iron impurities are derived from two sources—(1) Iron oxide originally present in the ore, and oxides resulting from the decomposition of pyrites during calcination ; and (2) metallic iron from the wear and tear of the stamps and other machinery used in handling the ore.

The ore from the calciner, after being allowed to cool, is distributed on a travelling belt. Above the belt are arranged four electro-magnets under which the ore passes successively as it travels along with the belt.

Under the poles of each magnet there is a narrow india-rubber band which travels at right angles to the belt upon which the ore is spread. By this means magnetic particles passing under the bands are picked up in a continuous stream and carried laterally, on the lower surface of the bands towards and over the edge of the belt, where escaping from the magnetic field they fall into a box. The first two magnets pick up iron and iron oxides. The next two are more strongly magnetized and pick up wolfram. Cassiterite with ordinary veinstone impurities falls over the end of the belt. The wolfram (from the last magnet particularly) may have to be passed through the machine a second time to free it from a little oxide of iron and also cassiterite dust which is carried along in the current of wolfram particles. Before finally ready for the market the wolfram requires treatment in a buddle.

The machine is designed to treat ten tons of concentrates daily. If the ore which is being treated contains copper, this is picked up with the oxide of iron resulting from the decomposition of the pyrites and so does not pass over the end of the belt with the tin.

The ordinary method of dressing the tin ore in the Camborne district, although variously modified according to the quality and fineness of the tin ore, does not include any means of classifying the stuff before concentrating it; and this is the chief difference between the ordinary and the newer processes in vogue in Cornwall. The ideal classifiers would be those which would accurately sort the particles according to size. If the pulp were dried this might readily be accomplished by sieves but it is found that there is still wanting a really practicable means of properly sizing the material. What is now done is to roughly classify the particles of stuff according to the speed with which they fall through water; and, for this purpose, the pulp from the stamps is led into upward current separators (or spitzluten). The upward current separators consist of a series of compartments, of the shape of inverted pyramids, through which the material flows successively from one end of the series to the other. At the apex of each compartment a stream of water is forced in at a pressure which can be regulated. The heavier particles can fall down into the compartment against the current and pass out by a small opening near the apex. The lighter materials flow over into the next compartment in which the upward current is less vigorous, so that another grade of stuff is allowed to separate, and so on. The various grades of stuff from the different compartments are dealt with separately. The stuff flowing over from the last compartment is known as slime. The slime is classified in another series of compartments (spitzkasten), which are similar in construction to the last but have no upward current.

In all the processes for the dressing of tin ore there is always an initial separation of the pulp into two main classes—the coarser grained material from which ultimately the coarse or "crop-tin" is obtained; and the finer material, or "slime," from which "slime-tin" is obtained. They are dealt with separately, as of course what is suitable for one is unsuitable for the other. A brief account of the actual methods adopted in the treatment of the ores at some of the mines in Cornwall is as follows:—

The ore is fed into the stamps and the pulp splashed through perforated plates (Gauge No. 36), and passed on to Frue vanners. The pulp is concentrated by the vanners. The concentrates are calcined and roughly classified in dumb pits (central feed buddles). Two products are obtained known respectively as "Head" and "Tail." The head is treated on buddles or else Rittinger tables and then it goes to the kieves where it receives final treatment before it is sent to the market. This concentrate is known as crop-tin. The tail from the Rittinger table or buddle is pulverised and passed over the vanners once more. The tail from the dumb pit is pulverised and treated on revolving tables and buddles, and finally in kieves when it is ready for the market and is known as "fine-tin." The tailings from the Frue vanners are classified in an

upward current separator. Two products are obtained called "sands" and "slimes." The "sands" flow into launders called "strips." Here the heavier material collects while the lighter flows to waste. The heavy material is pulverised and again treated on vanners. The tailings from the vanners in the treatment of this stuff pass over ragging frames with other products as about to be described. The slimes from the separator flow off into settling pits and thence to ragging frames. The concentrates from these pass into settling pits and then over revolving tables, after which the "head" is taken and calcined. After calcining the slime is again treated on revolving tables and the concentrate, known as "slime-tin," is ready for sale. The whole process is a complicated and tedious one, especially in the last stages. With the view of obviating this the recent plants aim at getting a classification as early in the process as possible, so that the waste from each operation may be allowed to run clean away.

The plant of the Gunnislake Clitters Company (Calstock) is one of the most recent in Cornwall. The ore treated at the present time is obtained from the mine and some old burrows; and it consists of wolfram, cassiterite, copper and arsenical minerals with ordinary veinstone materials. The plant could be modified in several ways without decreasing its efficiency, but the accompanying diagram illustrates the actual process used at Gunnislake Clitters Mine.

The "produce" varies considerably but lately it has been about eighteen pounds of metalliferous mineral per ton of stuff, of which fourteen pounds consist of tin and wolfram.

When the Greenhill burrow was being treated, about 100 tons a day were stamped and dressed at a cost of 2s. 8d. per ton (which includes cost of labour, coal, new gratings, wear and tear, etc.). The stuff now treated is harder and only seventy tons are stamped and dressed at a cost of about 5s. per ton.

The ore from the mine is dumped over a grizzly. The large stones are broken by jawstone-breakers and pass with the smalls to ore bins. The stuff is fed into twenty-five Californian stamps (arranged in fives) by Challenge feeders. Each stamp weighs 800 pounds and gives 80 blows a minute. Wire screens of 25-mesh (625 holes per square inch) are used in preference to perforated plates, thus avoiding the production of an excessive amount of slime. For convenience in case of ores requiring special treatment, the pulp from the five end stamps need not be mixed with that from the remaining twenty. The remaining twenty may be worked in batteries of ten independently of one another.

If the ore be of uniform character, it will be subjected to the following treatment. The pulp from the stamps passes into upward current separators (*see* Spitzluten in diagram) and thence to eight Buss tables. Two sets of separators have three compartments, and one has two. One set of separators takes the pulp from ten stamps; another from ten stamps; and the set with two compartments from five.

Ore from mine contains cassiterite, wolfram and sulphides of copper and arsenic (70 tons daily).

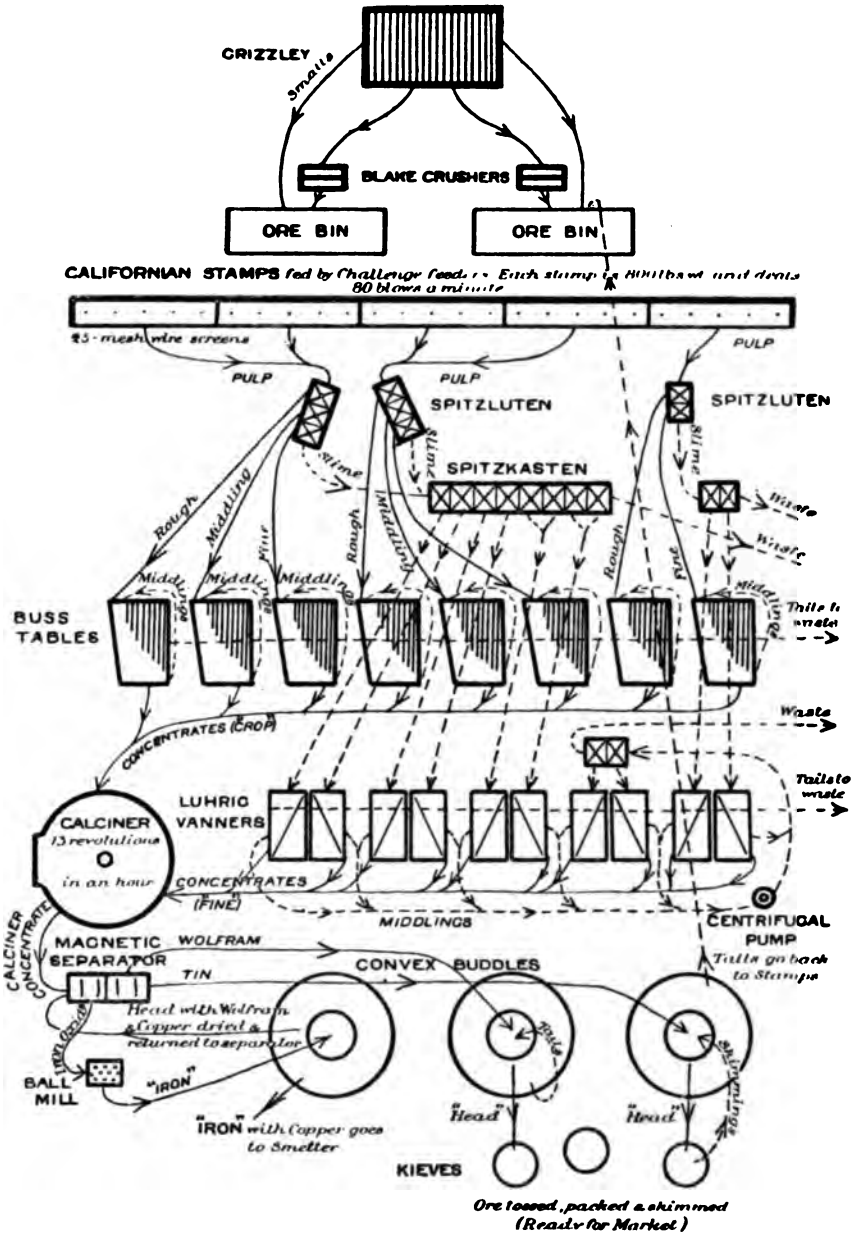


FIG. 3.—ORE-DRESSING PLANT OF THE GUNNISLAKE CLITTERS MINE.

The three compartments feed Buss tables with "coarse," "middlings" and "fine" respectively. The Buss tables concentrate the material fed on to them. The heads from the tables go to the calciner; the "middles" are returned to the tables by a raft-wheel; the tails flow to waste. The overflow (or slimes) from the upward current separators goes to spitzkasten (*see* diagram) which are arranged in one long series of ten compartments. The spitzkasten are similar to the spitzluten but have no upward current. The stuff from the spitzkasten goes to Luhrig vanners (revolving tables of the Acme type might be used with equal efficiency). The first four compartments feed four Luhrig vanners; after this each successive pair of compartments feeds one vanner, except the last two, each of which feeds one vanner. The overflow from the spitzkasten goes to waste. The "heads" from the vanners are sent to the calciner. All the middlings are raised by a centrifugal pump from the vanners to two spitzkasten each of which feeds a Luhrig vanner. The tails from all the Luhrig vanners go to waste.

In calcining, the "crop-tin" and wolfram from the Buss tables, and the "fine-tin" and wolfram from the Luhrig vanners are kept separate, but each in its turn undergoes practically the same treatment. The stuff from the calciner passes through a Wetherell electro-magnetic separator by which three products are obtained. The first is iron and iron oxides containing a little copper. This is sent to a ball mill (revolving thirty-three times a minute) and then to a convex buddle, by which the small amount of wolfram and tin it contains is separated. This is dried and sent through the magnetic separator again. The tails from the buddle are mainly iron oxide with a little copper.

The wolfram from the magnetic separator may also require to be passed through the magnetic separator again, after which it is sent to a buddle where it is freed from the last traces of "iron." The tails from this are buddled again. The head from the buddle goes to kieves where it is "tossed," "packed" and "skimmed."

The tin from the magnetic separator is buddled. The head is tossed, packed and skimmed. The skimmings are sent back to the buddle, while the tails from the buddle, if rough, are sent right back to the stamps (*see* diagram).

At King Edward Mine (situated on the upper part of South Condurrow Mine, Camborne), the ore contains tin with a little native copper. The pulp from the stamps overflows successively through three compartments of a set of upward current separators. The coarse material from the first compartment passes on to a Buss table; the less coarse stuff from the second is treated on a Frue vanner; the fine stuff from the third goes to a settling pit and is pulverised together with the tails from the Buss table, and passed through the spitzluten again. The overflow from the spitzluten goes into large spitzkasten from which it passes over ragging frames. The concentrates from all the processes, after being calcined, are treated on Acme tables.

In some of the small mines the dressing plant is very simple. There are no Frue vanners or shaking tables. The heavier parts of the pulp coming from the stamps settle in launders (called "Drags") in such a way that the richer materials ("head") is at the head of the launder, while the poorer ("Middling") is at the tail. These two grades settle in the launder and are dug out and separately handled. The head is sent to a buddle and the concentrate from this is treated in kieves. The "middlings" are dug out from the tail of the launder and treated in a buddle. The tails which flow continuously from the "drag" while the head and middling are being deposited, run into buddles, where they are treated again and again until they are sufficiently rich to go to the kieves. Such arrangements as these are unfitted for treating low grade ores.

III. Notes on the Railway-cuttings between Castle Cary and Langport, in Somerset.

BY HORACE B. WOODWARD, F.R.S.; WITH ANALYSIS BY DR. W. POLLARD.

This new railway is the second of the two links planned to connect the Great Western Railway *via* Reading and Newbury, with the main line at Taunton. The cuttings on the first link, between Stert and Westbury, in Wiltshire, have been previously noted.*

Commencing near Castle Cary Station, the railway traverses a short cutting in grey clay of the Lower Lias, the clay becoming yellowish and almost white near the surface. To this feature further attention will be drawn. A short distance further on the clay was overlain by gravel made up chiefly of oolitic rocks, with a few flints, and by loam; portions of the alluvial deposits of the river Brue, that extend over a considerable area near the village of Alford.† To the west of Alford Well Farm the gravel lies in irregular pockets on the Lias clay, and it is there covered with a comparatively stiff clay 5 or 6 feet thick, which fills inequalities in the gravel. The features might be explained by the slipping of masses of Lias clay over the gravel, but at the present time there is no adjacent higher ground from which the clay could have descended. On the floor of the railway a strong band of cement-stones was exposed—striking E. and W. and dipping southwards. A fragmentary specimen of *Ammonites* [*Arietites*] *Brookei* ? Sow. was here obtained. Owing to the concealment of gravel by the brown loam and clay, it is difficult to say how much of the area at Lovington is drift-covered, but the ground to the north of the village is largely alluvial.

West of the Lovington road the railway traverses Wheat Hill, and a fine cutting, 35 feet deep in places, has been opened in shales with occasional layers of cement-stone and decomposed

* Summary of Progress for 1898, 1899, pp. 187, 188.

† *See* "Geology of E. Somerset," *Mem. Geol. Survey*, 1876, p. 156.

ferruginous bands. The beds dip towards the east. *Ammonites Brookei* and lower down *Am.* [*Arietites*] *semicostatus* were here met with. A north and south fault with a downthrow of about 10 feet on the east was clearly shown—the fault-plane being marked by a broken vein of calc-spar.

West of the fault and nearer to the village of Wheathill, the beds yielded *Am.* [*Arietites*] *semicostatus*, *A. bisulcatus*, *Belemnites breviformis* ?, and *Gryphæa* (fragment). Further on, at a lower horizon, the clays become darker and more shaly.

West of Lower Wheathill Farm another cutting showed 12 or 14 feet of pale grey and darker grey clay, with alternating beds of limestone and clay, faulted in three or more places to the west, and otherwise bent and broken. These beds form the upper part of the Blue Lias limestones, and probably belong to the zone of *Ammonites Bucklandi*. To the south and south-west of East Lydford no cuttings had been made at the time of my visit.

To the south-west of Lydford and east of Keinton Mandeville, there was a fine section of the characteristic Blue Lias limestones and shales—dipping eastwards at about 3°. About 35 feet or more of strata were exposed. In the eastern portion of the cutting the sequence was as follows :—

Brown decalcified clay- - - - -	1 ft. 6 in. to 2 ft.
Pale grey calcareous and brashy clay - - - -	3 ft.
Grey limestone and clay - - - - - -	about 3 ft.
Blue limestone and shaly clay - - - - -	15 ft.

Successive layers of the blue limestone and blue clay became grey and finally pale grey or white as they were traced westwards to the outcrop ; the limestones changing more rapidly. Samples were collected from the same respective layers of limestone and clay at distances apart about 25 yards, and the specimens were analysed by Dr. Pollard, whose report is appended. I do not remember to have seen anywhere before so striking an exhibition of bleaching in the Blue Lias series, but I have noted the presence of white clays here and there in Lias areas, as in a lane-cutting north-west of Cricket Malherbe between Chard and Ilminster. After crossing the Keinton Road the rail traverses two old quarries in the limestones, where the strata dip south-westwards ; these beds belong to the zone of *Ammonites planorbis*.* At Withybed Lane the road-cutting showed clays and limestones in the upper part of the Blue Lias limestone series. Judging from the westerly inclination of these strata and the appearances further west of the basement beds of the Lower Lias, there is probably a fault between Withybed Lane and Combe Lane north of Charlton Adam —perhaps taking a N.E. and S.W. direction—but no cutting had been made. The shallow cutting west of Combe Lane showed thin beds of Lower Lias, near the junction with the Rhætic. Here *Cardinia* and *Ostrea liassica* were obtained by Mr. J. Pringle.

A fault a little further west brings on the Ostrea-beds of the

* " Jurassic Rocks of Britain," vol. iii., 1893, *Mem. Geol. Survey*, p. 77.

Lower Lias. In the cutting north-west of Abbey Farm, Charlton Adam, the following strata belonging to the basement portion of the Lower Lias, were exposed :—

Limestones and shales with *Ostrea liassica* - -	2 ft. to 3 ft.
Shelly limestone with *Modiola, Pleuromya* and many bivalves - - - - - - -	
Blue flaggy and compact limestones with little shale, *Ostrea liassica* - - - - - -	
Flaggy limestone-shales - - - - - -	3 ft.
Banded blue limestones - - - - - -	1 ft. 6 in.

These beds rise gently to the west where the limestone-shales and accompanying smooth limestones are well exhibited. In beds of this character I have frequently found *Ammonites planorbis*, but no examples were here obtained, although the beds were searched by Mr. John Pringle as well as by me. In addition to the species above mentioned, *Lima gigantea* was also found.

South-west of Charlton House there was a fine section of White Lias, comprising about 20 feet of hard beds of white limestone alternating with softer stone-beds and pale marls. The hard and compact beds of White Lias showed bored surfaces at several horizons. Here and there thin grey earthy limestones—the base of the Lower Lias, rested on White Lias.

The following species were obtained from the White Lias in the Railway-cutting, west of the Priory, Charlton :—

Astarte ?	Mytilus sp.
Cardinia sp.	Ostrea liassica, *Strickl.*
Cardium ?	Pecten valoniensis ? *Defr.*
Lima sp. (*cf.* L. gigantea, *Sow.*)	Pleuromya sp.
Modiola minima ? *Sow.*	Turritella ?

The section is continued westward through Sug Hill until the Black shales (*Avicula contorta* beds) of the Rhætic were exposed. Here the following fossils were found :—

Avicula contorta, *Portl.*	Placunopsis alpina, *Winkl.*
Myophoria sp.	Pleurophorus ?
Ostrea sp.	Protocardia rhætica, *Merian.*
Pecten valoniensis, *Defr.*	

Mr. J. Pringle noted that in a well west of Boxhill Lane a sandy layer full of fish-scales was passed through ; it probably represented one of the Rhætic Bone-beds.

He obtained the following species :—

Acrodus minimus, *Ag.*	Lepidotus sp.
Gyrolepis Alberti, *Ag.*	Saurichthys acuminatus, *Ag.*

The railway now follows the scarp below Green Down, and cuttings have been made in the grey marls at the junction of the Rhætic and Keuper ; further on in red and green marls, and finally in red marls near Wellham Farm and onwards towards Hurcot Farm.

Further west, the hill over which the Roman Road passes to the north of Somerton, was not opened up, but a trial pit about half-way between the Rifle Range and the Roman Road was excavated in Rhætic shales, and greenish and grey marls ; a second

pit a little east of the Roman Road was excavated in White Lias with ramifying cavities (? burrows); and a third pit west of the Roman Road and south-east of the angle in the plantation was excavated in White Lias and Black (*Avicula contorta*) shales. The ground thence westwards to the road by Brockle Cottage is strewn with fragments of Lower Lias, and it is probable that the Lias is here faulted against the Rhætic Beds. I am informed by Mr. John Morland, of Glastonbury, that in sinking for the foundations of the viaduct across the Cary Valley north of Somerton, the Contractors encountered, at a depth of about 30 feet, a bed of gravel formed of flint and chert stones very little rolled. The alluvium above included black peaty soil with hazel nuts.

The railway traverses Somerton, and on the southern side of the town the junction of Lower Lias and White Lias was again exposed north of Bower's Hill and on either side of the valley.

Further on by St. Cleer's Dairy House Lower Lias limestone and shale were exposed, and beyond there is a tunnel (1054 yards in length) with exit west of Long Sutton Plantations.

Here the basement portions of the Lower Lias limestone dip westwards at 6° or 7°, a position rather suggestive of slips at the mouth of the tunnel. The strata are even-bedded blue limestones and shales with paler beds at the outcrop, and they are slightly disturbed at one point. Mr. J. Pringle estimated the thickness shown at between 30 and 40 feet. Below, the White Lias was exposed (thickness 18 feet); then Grey shales 4 feet, and Black shales with *Avicula contorta* were traversed inside the tunnel to a thickness of 6 feet, beyond which the beds were faulted.

Some further particulars of the strata passed through in the tunnel were obtained by Mr. John Pringle. At the First air-shaft west of Ricksey Lane, S.W. of Somerton, the strata penetrated were Blue Lias 14 feet, White Lias 18 feet, Grey shales 4 feet, and then the Black *Avicula contorta* shales were proved from 36 to 40 feet below the surface. They yielded *Avicula contorta*, *Myophoria postera*, *Pecten valoniensis*, and *Pleurophorus* ? The strata rise westwards towards the mouth of the tunnel, the grey marls and red and green marls with gypsum being traversed, but they are faulted against the Black shales before the mouth is reached, there being a downthrow of about 20 feet on the west. This line of disturbance was traced out many years ago by Mr. Ussher, and marked on the Geological Survey Map, Sheet 18 (old series).

From the Black (Rhætic) shales near the western entrance to the tunnel, near Burnt House Lane, Mr. Pringle obtained the following fossils: —

Avicula contorta, *Portl.*
Modiola ?
Myophoria postera, *Quenst.*
Pecten sp.
Placunopsis alpina, *Winkl.*
Protocardia rhætica, *Merian.*
Lepidotus ? (scale).

In the White Lias above, ***Modiola minima*** ? only was found. From the Lower Lias the following species were obtained :—

Ammonites [Psiloceras] planorbis, *Sow.*	Modiola minima, *Sow.*
Pinna ?	Lima gigantea, *Sow.*
Pecten textorius, *Schloth.*	Avicula, sp.
Pecten valoniensis ? *Defr.*	Anomia, sp.
Ostrea liassica, *Strickl.*	Hemipedina (spines).
	Pentacrinus (columnals).

In a cutting on the new road north of the railway, and west of the tunnel, a striking faulted anticline was shown in the Lower Lias. (*See* Fig. 4.)

The even-bedded brown and blue limestones and shales belonging to the lower part of the Lower Lias have been opened up in the cutting at Upton, and between Hermitage Road and Tengore Lane the beds are slightly faulted with a downthrow on the east. Beyond Tengore Lane the beds are again disturbed and bent, and faulted in one or two places.

In the cutting west of Upton Farm, Mr. Pringle obtained *Ostrea liassica*, *Modiola minima*, *Lima* (cf. *L. gigantea*), *Gervillia crassa*, and *Hemipedina* (spine).

West of Wagg Drove and Rhyne there is a cutting in the Rhætic Beds, showing White Lias, faulted a little east of the Union Drove bridge. To the west of the bridge the White Lias, Black Shales and Grey Marls appear, the beds dipping eastwards. At the western end of the cutting the Black Shales which are from 15 to 18 feet thick, were divided by a wedge-like band, 2 feet thick, of grey sandy shales and clays, not unlike the grey marl series below. This feature together with the band of grey shales above the mass of black shales, shows the intimate connection between the White Lias and the grey marls which pass down into the red and variegated Keuper Marls. (*See* Fig. 5.)

West of the Mill Brook the cutting which extends to the Langport and Somerton road on the borders of the marshlands, is in the red and green Keuper Marls with hard pale bands and with irregular coverings of gravel.

At one point on the south side near the Mill Brook, the cutting, here about eight feet deep, showed the green and harder pale marls much broken up and converted into a tufaceous marl, and the gravel contained portions of these broken bands.

Nearer the road the Keuper Marls were disturbed and faulted, as shown in the banks of the new road-cuttings north of the School.

Westwards the railway crosses the Alluvium of the river Parret, over a portion of Aller Moor, which is a part of Sedgemoor, and here foundations of the piers for a viaduct have had to be sunk to a depth of fifty feet through peat and alluvium. The railway connects with the Yeovil and Taunton branch about half-a-mile north-west of Langport station.

[*N.B.*—The fossils enumerated in these notes were all named in the Palæontological Department.]

FIG. 4.—*Section on new road north of the Castle Cary and Langport Railway, north-west of Upton, near Long Sutton.*

W

Lower Lias limestones and clays.

E W

FIG. 5.—*Section on the Castle Cary and Langport Railway south-west of Langport Union Workhouse.*

	Ft.
F. White Lias.	
E. Dark grey and rusty shale	4
D. Bands of pale and bluish earthy limestones with mammillated surface	2
B. Black shales	14
C. Grey sandy shales and clays, tapering away eastwards	2
B. Black shales	4 or 5
A. Yellowish grey marls and shales — laminated beds — the top layer a yellowish clayey bed indented by black shales with bones. Seen to depth of	10

NOTE ON THE CHANGE IN COLOUR IN THE CLAYS AND LIMESTONES OF THE LOWER LIAS, FROM THE RAILWAY-CUTTING, EAST OF KEINTON MANDEVILLE, SOMERSET.

BY WILLIAM POLLARD, M.A., D.SC., F.G.S.

The specimens submitted for examination were :—

1. Blue Clay, passing into (2) whitish clay at outcrop. (3) Blue Limestone, passing into (4) whitish limestone at outcrop.

Partial analyses of the above gave :—

	1.	2.	3.	4.
Residue insol. boiling hydrochloric acid, ignited.	50·33	30·96	10·96	11 65
SiO_2	1·27	1·73	·71	1·42
Fe_2O_3	1·23	2·53	1·01	1·43
Al_2O_3, etc.	1·12	1·14		
CaO	20·31	32·36	47·21	46·14
MgO	1·22	·77	·98	·77
H_2O 105°C.	2·89	2·26	·54	·66
Loss on ignition (above 105°C.)	20·68	28·11	38·16	37·80
SO_3	·28	·15	·16	·13
S (as FeS_2)	1·09	·37	·32	·03
	100·42	100·38	100·05	100·03
Less O for S.	·41	·14	·12	·01
Total	100·01	100·24	99·93	100·02

The residues from Nos. 1 and 3 were almost black (No. 3 less than No. 1) in appearance, and when ignited gave a smell of petroleum. No. 1 contained considerable organic matter. Nos. 2 and 4 contained very little, and were only greyish in colour.

Nos. 1 and 2 are not strictly comparable, as 2 is so much richer in lime, which suggests either that they did not come from the same bed or that the bed varies greatly in composition. Had weathering been the cause of the difference in all probability No. 2 would have been richer in residue and poorer in lime than No. 1. There is, however, sufficient to show that the cause of No. 2 being lighter in colour is the much smaller amount of organic matter and pyrites which it contains.

In Nos. 3 and 4 the results are more easily comparable, and the following differences can be observed. (Although the differences of general composition may be due to variation as in the former case, they appear to be more probably due to weathering.) The sum of the residue silica, iron and alumina, increases in the weathered specimen, whilst the lime, magnesia and loss on ignition, —mainly due to CO_2 combined with these,—slightly decrease, which would be the effect of exposure to the weather and consequent extraction by water. The organic matter and pyrites, as in Nos. 1 and 2, both diminish in the weathered specimen.

From the above I think it is clear that the change from blue to whitish is due to the disappearance of the organic matter and the pyrites brought about by the action of the weather.

IV. Notes on the Railway-cuttings between Clarbeston and Letterston in Pembrokeshire.

* BY H. H. THOMAS, M.A., F.G.S.

By the kindness of the Great Western Railway Company and the Contractors of the Clarbeston to Goodwick Railway a preliminary inspection was made of the various exposures along the route from Clarbeston Road through Trefgarn, to Letterston, where the new railway will join the already constructed branch from Clynderwen to Fishguard.

In the main-line old cutting at Clarbeston Road* the black *Dicranograptus* shales are well exposed under the bridge.

A little to the west a fault brings in the higher members of the Bala series, and cuts out the calcareous beds which ought to occupy the intermediate position. Further along the line the Redhill Beds are well exposed for about one third of a mile from Clarbeston Road Station and at this point the junction with the new railway is reached; the widening of the line here reveals a good section in the Redhill Beds, in an almost vertical position and striking east and west. For a distance of a little less than half a mile nothing is seen but yellow gravelly drift, but a little further to the west, to the south of Upper Haythog, is a short cutting in Redhill Beds followed by a considerable drift covered area. At Lower Haythog Farm a cutting in Redhill Beds commences and continues across the Scolton Road, but at present has only been driven for 300 yards from the farm. The beds continue to strike east and west and are vertical; they contain abundant *Trinucleus*.

The line at Scolton Road takes a slight bend to the north west and from this point forward for about a mile runs over drift.

Excavations through the drift at two culverts have exposed good black *Dicranograptus* Shales with a northerly dip. These shales occupy the whole of the course of the line from the Scolton Road to the Spittal Road where will start the cutting which leads to the Trefgarn Tunnel.

From trial holes, etc., it is evident that *Dicranograptus* Shales occupy the ground for 200 yards to the N.W., of the Spittal Road. At this point a marked change is noticed in the soil and, from here to the tunnel-heading on the other side of the hill, the ground consists of a pale-weathering igneous rock.

The tunnel is being driven from north to south and enters the hill at about seventy feet above the level of the Cleddau Valley at Trefgarn bridge. The heading shows a beautiful section in the *Lingula* Flags and Archæan rocks. The flags at the northern end of the heading are olive-green with siliceous bands; towards the south the flags become more gritty and the hard bands thicken, while the dip falls to about 15°; they pass down into a massive conglomerate about six feet thick made up of rounded blocks of the underlying igneous rocks, often as much as one foot in diameter.

* Marr and Roberts, *Quart. Journ. Geol. Soc.*, vol. xli., p. 481-2 (1885).

The conglomerate rests immediately on hard blue andesites and andesitic tuffs with a set of almost vertical planes.

The quarry, where Dr. Marr (*op. cit.*) first recorded what he considered to be the conglomeratic base of the *Lingula* Flags, lies 150 yards due west of the tunnel heading. There the section consists of the same blue rock wrapped around by a conglomerate and flags. The section in the tunnel heading is, however, vastly superior.

This pre-cambrian mass evidently comes to the surface between the Spittal Road and Trefgarn Bridge. At the same time it is probable that it is almost enveloped by the flags, except on the south side where it is faulted against the *Dicranograptus* Shales. The tunnel will ultimately be driven through the faulted junction between the Archæan and *Dicranograptus* Shales. The distance to be driven through Archæan rocks is roughly estimated at 950 feet. The rocks through which the tunnel is being driven and which are exposed in the quarry at Trefgarn Bridge appear to be pyroxene andesites, all more or less decomposed, and their associated tuffs. Rocks of similar character and age which occur to the east of Trefgarn have undoubtedly been andesites. No ferro-magnesian mineral now remains in these rocks, but the pseudomorphs lead to the conclusion that both augite and hypersthene were represented in the original masses.

From Trefgarn Bridge northwards little has yet been done in the way of cuttings.

Interesting sections in the drift have been exposed at Chapel Farm south of Ford. The boulders consisted largely of a blue diabase probably of northerly derivation. At Chapel Farm will start a long and most interesting cutting, crossing the junction between the Cambrian and Ordovician rocks.

Near Heathfield, one and a half miles north-west of Letterston, a cutting has been started from the north in highly cleaved, ashy, unfossiliferous flags, which probably belong to the *Didymograptus Murchisoni Zone.*

V.—Catalogue of Types and Figured Specimens of British Lamellibranchiata from the Rhætic Beds and Lias, preserved in the Museum of Practical Geology, London.

BY H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed :—

Geol. Mag. : The Geological Magazine, London.

Mon. Pal. Soc. : Monographs of the Palæontographical Society, London. "A Monograph of the British fossil Trigoniæ." by John Lycett, 1872-1883.

Q. J. G. S. : Quarterly Journal of the Geological Society of London.

Belfast Nat. Field Club : Seventh Annual Report of the Belfast Naturalists' Field Club, Belfast.

"Yorkshire Lias" : R. Tate & J. F. Blake, "The Yorkshire Lias," London. (The dates quoted refer to year of issue only.)

RHÆTIC.

Anatina præcursor, Quenstedt, *var.* **pylensis**, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, p. 88.
Rhætic (*Avicula-contorta* zone). [7826] Pyle, Glamorganshire.

Avicula contorta, Portlock. **T.**
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xxv*a*. f. 16, p. 126.
Rhætic. [7821] Larne.

Pecten valoniensis, Defrance.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xxv *a*, f. 14, p. 127.
Rhætic. [7822] Larne.

LIAS.

Anatina myacina, Tate.
R. Tate, Belfast, Nat. Field Club, 1870, App. I., pl. i, f. 16, p. 22.
Lower Lias (*A. anglatus* zone). [7871] Island Magee.

Arca numismalis, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 3, p. 406.
Lower Lias (*A. Jamesoni* zone). [7850] Aston Magna.

Arcomya concinna, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 1, 1*a*, p. 411.
Middle Lias (*A. spinatus* zone). [7873, 7874] Eston.

Arcomya longa (Buvignier).
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 11, p. 410.
Middle Lias (*A. spinatus* zone). [7875] Eston.

Arcomya vetusta (Phillips).
R. Tate, "Yorkshire Lias," 1876, p. 410.
Lower Lias (*A. armatus* zone). [7870] Robin Hood's Bay.

Astarte dentilabrum, Etheridge. **T.**
R. Etheridge, Q. J. G. S. vol. xx., 1864, p. 113, figs. 5–7 (Text-figures).
Lower Lias. [7995] Larne.

Astarte Duncani, Tawney. T.
E. B. Tawney, Q.J.G.S., vol. xxii., 1866, pl. iv., f. 4, p. 87.
Lower Lias (Sutton Stone). [7859] Sutton.

Astarte Oppeli, Andler.
R. Tate, "Yorkshire Lias," 1876, pl. xii., f. 3, p. 387.
Lower Lias (*A. angulatus* zone). [12040] Redcar.

Astarte striato-sulcata, Roemer.
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 7, p. 388.
Middle Lias (*A. spinatus* zone). [7858] Eston.

Avicula longiaxis, Buckman. T.
J. Buckman in Murchison, "Geol. Cheltenham," 1845, pl. x., f. 2, p. 97.
Lower Lias. [3675] Battledown Hill, Cheltenham.

Avicula Pattersoni, Tate. T.
R. Tate, Belfast Nat. Field Club, 1870, App. I. pl i, f. 10, p. 18.
Lower Lias (*A. angulatus* zone). [7831] Island Magee.

Cardinia crassiuscula, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xiv., f. 4, p. 389.
Lower Lias (*A. Bucklandi* zone). [7862] Redcar.

Cardinia ingens, Tawney. T.
E. B. Tawney, Q.J.G.S., vol. xxii., 1866, pl. iv., f. 2, p. 86.
Lower Lias (Sutton Stone). [7861] Sutton.

Cardinia lævis. Young and Bird.
R. Tate, "Yorkshire Lias," 1876, pl. xi., f 12, p. 391.
Middle Lias (*A. spinatus* zone). [7860] Eston.

Cardinia suttonensis, Tawney. T.
E. B. Tawney, Q.J.G.S., vol. xxii., 1866, pl. iv., f. 3, p. 86.
Lower Lias. [7863] Sutton.

Cardita multicostata, Phillips.
R. Tate, "Yorkshire Lias," 1876, pl. xii., f. 7, 7*a*, p. 388.
Middle Lias. [7866] Staithes.

Cardita? rhomboidalis, Tawney. T.
E. B. Tawney, Q.J.G.S., vol. xxii., 1866, pl. iv., f. 6, p. 87.
Lower Lias. [7864] Sutton.

Ceromya gibbosa, Etheridge. T.
R. Etheridge, Q.J.G.S., vol. xx., 1864, pp. 112, 113 (Text-figure).
Lower Lias (*A. angulatus* zone). [7872] Island Magee.

Ceromya sublævis, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xii., f. 6, 6*a*, p. 408.
Middle Lias (*A. spinatus* zone). [7892, 7893] Eston and Hobb Hill.

Ceromya petricosa (Simpson).
R. Tate. "Yorkshire Lias," 1876, pl. xiv., f. 1, p. 408.
Middle Lias (*A. margaritatus* zone). [7891] Staithes.

Cucullæa Grangeri, Tate. T.
R. Tate, Belfast Nat. Field Club, 1870, App. I. pl. i, f. 12, p. 19.
Lower Lias. [7851] Ballintoy, Ireland.

Cyprina normalis, Tawney. T.
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. 4, f. 7, p. 87.
Lower Lias. [7865] Sutton.

Gervillia crassa, Buckman. **T.**
J. Buckman, in Murchison, "Geol. Cheltenham," 1845, pl. x., f. 9, p. 98.
Lower Lias. [3684] Between Gloucester and Bredon.

Gervillia lævis, Buckman. **T.**
J. Buckman, in Murchison, "Geol. Cheltenham," 1845, pl. x., f. 8, p. 98.
Lower Lias. [3683] Battledown Hill, Cheltenham.

Gervillia ærosa, Simpson.
R. Tate, "Yorkshire Lias," 1876, pl. xiv., f. 6, p. 373.
Lower Lias (*A. capricornus* zone). [7832] Staithes.

Gresslya intermedia (Simpson).
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 8, p. 403.
Middle Lias (*A. margaritatus* zone). [7879] Cleveland.

Gresslya Seebachii, Brauns.
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 3, p. 402.
Middle Lias (*A. margaritatus* zone). [7878] Huntcliff.

Hinnites angularis, Tate. **T.**
R. Tate, Belfast Nat. Field Club, 1870, App. I., pl. i., f. 2, p. 18.
Lower Lias (*A. angulatus* zone). [7828] Island Magee.

Hippopodium ferri (Cross MS.), Etheridge. **T.**
R. Etheridge, Q. J. G. S., vol. xxxi., 1875, pl. v., f. 6, pp. 119, 128.
Lower Lias (*A. semicostatus* zone). [7868] Scunthorpe.

Hippopodium gigas, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 5, p. 392.
Middle Lias (*A. spinatus* zone). [7867] Eston.

Inoceramus incurvatus, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 2, 2*a*, p. 407.
Lower Lias (*A. capricornus* zone). [7833] Cheltenham.

Leda æquilatera, Koch and Dunker.
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 10, p. 382.
Upper Lias (*A. jurensis* zone). [7910] Peak, Yorkshire.

Leda galathea, d' Orbigny [= **Galatea**.]
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 5, p. 383.
Middle Lias. [7883] Cleveland.

Leda graphica, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 12, p. 407.
Middle Lias (*A. capricornus* zone). [7885] Mickleton Tunnel.

Leda graphica, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 4, p. 386.
Middle Lias (*A. capricornus* zone). [7884] Staithes.

Leda minor, Simpson.
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 9, p. 383.
Middle Lias. [7888] Cleveland.

Leda Renevieri, Oppel.
R. Tate, Belfast Nat. Field Club, 1870, App. I., pl. i. f. 3, p. 19
Lower Lias (*A. Bucklandi* zone). [8008] Glynn, Larne.

Leda Renevieri, Oppel.
R. Tate, "Yorkshire Lias" 1876, pl. xi., f. 4, p. 384.
Lower Lias (*A. Bucklandi* zone). [7887] Marske.

Leda texturata, Terquem & Piette.
R. Tate, "Yorkshire Lias," 1876, pl. xii., f. 8, p. 385.
Lower Lias (*A. angulatus* zone). [7885] Redcar.

Leda v-scripta, Tate. T.
R. Tate, Belfast Nat. Field Club, 1870, App. I., pl. i., f. 5, p. 19.
Lower Lias (*A. angulatus* zone). [7886] Waterloo, Larne.

Lima angusta, Tawney. T.
E. B. Tawney, Q. J. G. S., vol. xxii, 1866, pl. iii., f. 6, p. 83.
Lower Lias. [7838] Sutton.

Lima dunravenensis, Tawney. T.
E. B. Tawney, Q. J .G. S., vol. xxii, 1865, pl. iii., f. 9, p. 83.
Lower Lias. [7837] Dunraven Castle.

Lima planicostata, Tawney. T.
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 7, p. 83.
Lower Lias. [7841] Sutton.

Lima scabricula, Tate. T.
R. Tate, Q. J. G. S. vol. xxvi, 1870, pl. xxvi., f. 15, p. 406.
Lower Lias (*A. Jamesoni* zone). [7839] Aston Magna, Gloucestershire.

Lima subduplicata, Tawney. T.
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 8, p. 83.
Lower Lias. [7840] Sutton.

Limea blakeana, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xiv., f. 5, p. 368.
Lower Lias (*A. angulatus* zone). [7842] Redcar.

Lucina cardinoides, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xvi., f. 8, p. 395.
Lower Lias (*A. Bucklandi* zone). [7852] Redcar.

Macrodon clevelandicus, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 6, p. 381.
Middle Lias (*A. spinatus* zone). [7848] Eston.

Macrodon pulchellus, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 2, p. 381.
Lower Lias (*A. Jamesoni* zone). [7849] Kirkby Underdale, Yorks.

Modiola subcancellata, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 1, p. 378.
Middle Lias (*A. margaritatus* zone). [7846] Huntcliff, Yorkshire.

Modiola bifasciata, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. xi., f. 3 p. 379.
Lower Lias (*A. Bucklandi* zone). [7844] Redcar.

Modiola imbricato-radiata, Tawney. T.
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iv., f. 8, p. 87.
Lower Lias. [7843] Sutton.

Mytilus subtilis, Tate. T.
R. Tate, Belfast Nat. Field Club, 1870, App. I. pl. i., f. 14, p. 20.
Lower Lias. [7845] Cave Hill, Belfast.

Nucula ungulella, Tate. T.
R. Tate, Q. J. G. S. vol. xxvi., 1870, pl. xxvi., f. 11, p. 407.
Lower Lias (*A. Jamesoni* zone). [7890] Cheltenham.

Opis Deslongchampsi, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 9.
Middle Lias (Marlstone). [7869] Uley, Gloucestershire.

Ostrea lævis, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 2, p. 84.
Lower Lias (Sutton Stone). [7814] Sutton.

Ostrea multicostata, Muenster *non* Deshayes.
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 1, p. 84.
Lower Lias. [7815] Sutton.

Pecten Etheridgei, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 4, p. 81.
Lower Lias (Sutton Stone). [7829] Sutton.

Pecten suttonensis, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 3, p. 81.
Lower Lias. [7830] Sutton.

Perna? Ramsayi, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, p. 86.
Lower Lias. [7835] Southerndown.

Pholadomya ventricosa (Agassiz).
R. Tate, "Yorkshire Lias," 1876, p. 399.
Lower Lias (*A. Bucklandi* zone). [7876] Marske.

Pinna Hartmanni, Zieten.
R. Tate, "Yorkshire Lias," 1876, p. 376.
Lower Lias (*A. Bucklandi* zone). [7836] Redcar.

Pinna insignis, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iii., f. 5, p. 85.
Lower Lias. [7834] Dunraven.

Pleuromya bituminosa, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. xii., f. 9, p. 405.
Upper Lias (*A. serpentinus* zone). [7911] Skelton Park.

Pleuromya costata (Young and Bird).
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 9, p. 404.
Middle Lias (*A. spinatus* zone). [7882] Kettleness.

Pleuromya crowcombeia, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 10, p. 406.
Lower Lias. [7770] Eston.

Pleuromya granata (Simpson).
R. Tate, "Yorkshire Lias," 1876, pl. xiii., f. 7, p. 405.
Middle Lias (*A. margaritatus* zone). [7881] Staithes.

Pleuromya mundula, Tate. **T.**
R. Tate "Yorkshire Lias," 1876, pl. xii., f. 11, 11*a*, p. 406.
Middle Lias (*A. margaritatus* zone) [7880] Huntcliff.

Tancredia liassica (Cross, MS.) Etheridge. **T.**
R. Etheridge, Q. J. G. S., vol. xxxi., 1875, pl. v., f. 5, 5*a*, pp. 120, 127.
Lower Lias (*A. armatus* zone). [7853] Sheffield Hill, Lincolnshire.

Thracia æquata, Tate. **T.**
R. Tate, Belfast Nat. Field Club, 1870, App. I., p. 22.
Lower Lias (*A. angulatus* zone). [7889] Waterloo, Larne.

Trigonia Leckenbyi, Lycett. T.
J. Lycett, Mon. Pal. Soc., 1874, pl. xvi., f. 2, p. 71.
Upper Lias. [11731] Robin Hood's Bay.

Trigonia lingonensis, Dumortier.
J. Lycett, Mon. Pal. Soc., 1875, pl. xxii., figs. 1, 1*a*, 2., p. 98.
Middle Lias. [11839, 11840] Eston.
Ibid. pl. xxii., f. 3, p. 98.
Middle Lias. [11841] Hobb Hill Mine, Saltburn.
Ibid. pl. xxii., f. 4, p. 98.
Middle Lias. [11842] Challoner Mine, Guisborough.

Trigonia literata, Young & Bird.
J. Lycett, Mon. Pal. Soc., 1874, pl. xiv., figs. 1, 1*a*, 2, 3, 4, p. 64.
Upper Lias. [11732–11735] Robin Hood's Bay.

Trigonia pulchella, Agassiz.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxviii., figs. 10–12, 12*a*, p. 185 ; *Ibid.* Suppl., 1883, pl. iii., figs. 7–12, p. 11.
Upper Lias (*A. communis* zone). [11407–11409, 11402–11406] Lincoln.

The following lists of British type-fossils have been published in the "Summary of Progress" and *issued* in the years stated :—

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Pliocene, Pleistocene and Devonian	1901.
Phyllocarida and Palæozoic Echinodermata	1902.
hæ tic, Lias, and Inferior Oolite Gasteropoda	1903.
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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

AND

MUSEUM OF PRACTICAL GEOLOGY

FOR

1905.

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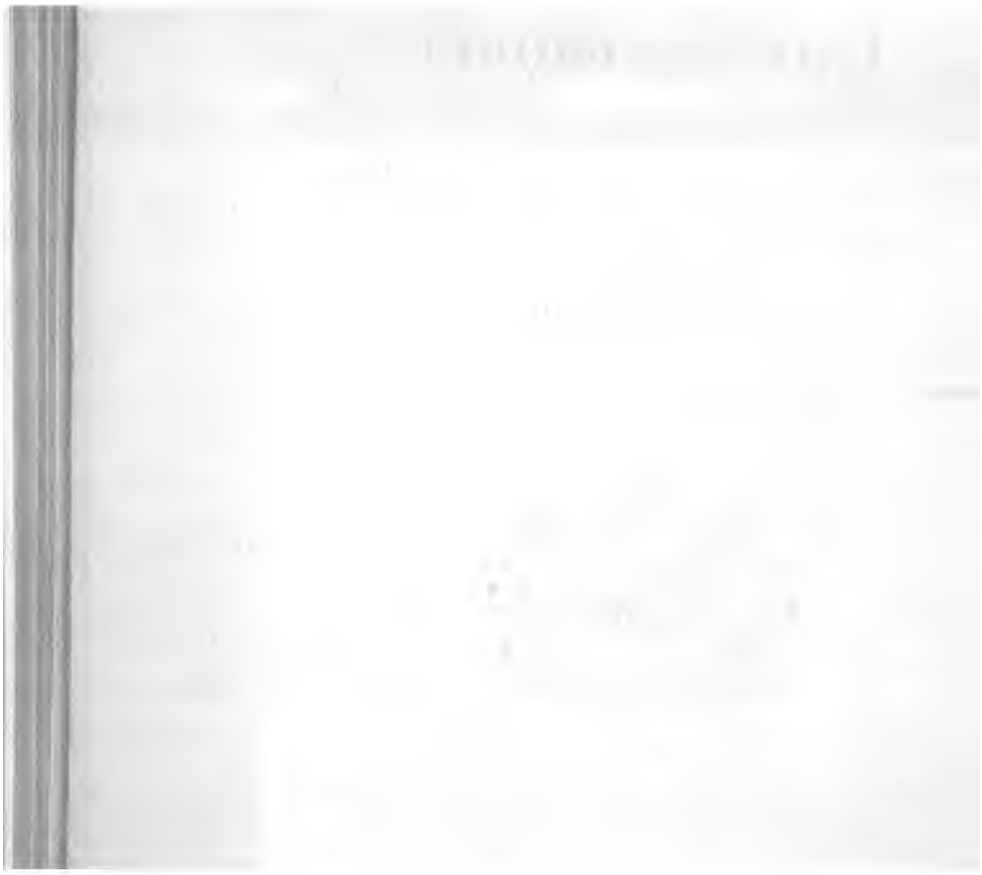

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1905.

INTRODUCTION.

BY J. J. H. TEALL, M.A., D.Sc., F.R.S., DIRECTOR.

In England and Wales field-work has been continued in Cornwall, South Wales, the Midlands and the neighbourhood of Oxford. The work in the Oxford district, which was undertaken for the purpose of preparing a special map and memoir of that district, has been concluded; but that of the other districts is still in progress. In Cornwall the survey is proceeding from west to east, and the more important mineral districts have already been completed. There has been considerable delay in publication in consequence of the difficulty of arriving at a conclusion as to the age of the unfossilferous rocks in the western portion of the country; but, during the year under review, a decision has been arrived at, and publication is now being pushed forward as rapidly as possible.

In South Wales the work is proceeding from east to west, and the re-survey of the coal field is rapidly approaching completion. In the Midlands the re-mapping of the Nottinghamshire and Derbyshire coal-field has been continued northwards towards the southern boundary of the Yorkshire coal-field which was originally surveyed on the six-inch scale. In Scotland progress has been made with the original survey of the northern and western Highlands and with the revision of the Carboniferous rocks of the Glasgow and Airdrie districts.

Highland Metamorphic Rocks.

The work on the crystalline rocks of the northern Highlands, in the district traversed by Glen Strath Farrar, Glen Orrin and Glen Meig, has proceeded on the lines laid down in previous summaries. It consists in separating out from the so-called Moines those areas in which the rocks have decided affinities with certain types of Lewisian gneiss. That this method of mapping is not only justifiable but necessary, I satisfied myself during an inspection of the ground in the neighbourhood of Scardroy

Highland Metamorphic Rocks.

and Loch Beannachan; but I am unable, from my own limited observations, to express any opinion as to the original relations of the Moine rocks to the complex gneisses of Lewisian type. One point is, however, abundantly clear: whatever the original relations were, both rock-groups have been folded together and have taken on, in certain places, a common type of structure and a common foliation. The published statements of more than one observer also make it clear that the line separating the two groups is sometimes one of marked discordance, so that different types of rock in each group abut against it. The view which finds most favour at present with those who are surveying the district is that the Moine rocks were originally sediments deposited unconformably upon an old floor of Lewisian gneiss; but whatever the ultimate view may be on this point there can be no doubt that in general the areas that we are representing on our maps as Moines are, as a whole, distinct from those represented as Lewisian gneiss.

A most important feature of the past season's work has been the discovery, in areas of the Lewisian gneiss type, of a series of altered sedimentary rocks, including crystalline limestones, calc-silicates, brown mica-schists, &c. As the work progresses it will be of great importance to note whether these altered sediments can in all cases be separated sharply from the Moines. It must be born in mind that in the pre-Torridonian areas of the west there are extensive tracts of altered sediments, some of which have the typical moine-like character, and that these were referred to long ago by Dr. Hicks as tending to link together the eastern and the western gneisses. But, as I stated in my Introduction to the Summary of Progress for 1904, the problem here raised is one of so much importance, from the point of view of the structure and geological history of the Highlands, that its full discussion may be allowed to stand over until the entire area has been surveyed. A summary of the growth of opinion on the subject of these Lewisian inliers, of their distribution and of their petrographical characters, will be found in an appendix.

In the West Highland District further progress has been made, and both in Glencoe and Knapdale a great zone of quartzite at the base of the Ardrishaig series has been recognised. It is proposed to call this the Glencoe quartzite, to distinguish it from the Loch Awe or Schichallion quartzite, which has not unfrequently been termed the quartzite of the Central Highlands.

Lower Palæozoic.

In South Wales the mapping of the Lower Palæozoic rocks which fall within the areas of the one-inch sheets of the coalfield has been continued westward. On the old maps little or no detail is shown in these areas. Limestones are indicated, but no attempt is made to divide up the sediments into distinct groups. In previous Summaries it has been pointed out that representatives of the various subdivisions (Tremadoc, Llandilo, Bala and Llandovery) have been identified and mapped, and that the structure which is thus brought out consists of

compound anticlines and synclines, frequently accompanied by inversion and modified by numerous strike-faults and over-thrusts. The direction of over-folding and over-thrusting is from the north. The work of the year lay in the neighbourhood of St. Clears, Whitland and Lampeter Velfrey, and furnished further illustrations of these features. Lower Palæozoic.

In Cornwall the most important result has been the recognition of a strong unconformity between certain conglomerates and associated rocks of the Manaccan district and the underlying Portscatho and Veryan series. The age of the conglomeratic series has not been definitely settled by fossils, though a most careful search has been made; but other lines of evidence* point so strongly to the conclusion that the conglomerate is Devonian, that it has been decided to adopt this view and to give expression to it on the maps. The underlying rocks are, therefore, now classed as Lower Palæozoic. This is undoubtedly true of the fossiliferous quartzites and limestones; but, in the absence of fossils, the exact age of the Portscatho, Falmouth and Mylor groups cannot be determined.

The decision to represent these rocks as Lower Palæozoic has necessitated the drawing of a line between rocks of Upper and Lower Palæozoic age in North Cornwall; and this is attended with some difficulty in consequence of infolding due to post-Devonian earth-movements, the obscure nature of much of the ground, and the absence of any persistent band of conglomerate. But the strong grits of Grampound and Ladock are sharply differentiated from the Portscatho rocks to the south; and their base, or its equivalent in areas where the strong grits are absent, has been taken as the line of separation. It is interesting to note that this line was suggested as the base of the Devonian by Mr. Ussher in 1891.

In the areas occupied by Devonian rocks, in which work has been carried on during the year, the most interesting results, so far as Cornwall is concerned, relate to the granites, and the contact metamorphism produced by their intrusion. Devonian.

The re-survey of the boundaries of the granite masses has led to an important modification of the earlier maps in one respect. No case has been found of an elvan dyke forming an apophysis of one of the larger granite masses; but evidence has been obtained that the elvans cut both the granite and the surrounding rocks. The long, narrow, east and west apophyses, which are represented as extending outwards from the western margin of the Bodmin mass will, therefore, disappear from the geological map of the district.

Special attention has been paid to the effects produced by the granite masses of St. Austell and Bodmin on the various types of Devonian sediment and the associated igneous rocks. The phenomena are similar to those so well described many years

* The Older and Newer Palæozoics of West Cornwall, by J. B. Hill, *Geol. Mag.*, 1906, p. 206.

Devonian. ago by Allport* and more recently by Worth† and Busz‡ from other parts of the west of England. In addition to the rocks common to all granite-contact-zones we find those which are characteristic of the action of tourmaline-bearing granites. The boron and fluorine compounds which were given off during the final stages of consolidation of the granite-magma produced such rocks as tourmaline-hornfels and axinite-hornfels in the surrounding sediments; and gave rise to greisen, schorl-rock, and china clay by acting on the granite itself. Some excellent examples of both types of this pneumatolytic action, as it is usually called, have been met with during the year, and are referred to in the following pages.

The Old Red Sandstone facies of the Devonian has been studied on both sides of the Pembrokeshire coal-field. On the north side it is known to disappear a few miles westward of the area in which work has been done; but the cause of this is not yet apparent, for the thickness, which is estimated at about 3,000 feet, is maintained; and the diminution in the width of the outcrop is due to a progressive increase in the dip of the measures as they are traced westward. On this side the Lower Old Red only is known to occur, but on the south side the Upper Old Red appears to be represented by the quartzite series referred to in last year's Summary. Further evidence of this has been obtained by the discovery of two palatal fish-teeth closely allied to Carboniferous forms.

In Scotland further progress has been made with the survey of the volcanic rocks of Lower Old Red Sandstone age in the Glencoe and Dalness area, and with that of the sediments of the Middle and Upper Old Red Sandstone of Caithness. Of special interest is the evidence recorded in the following pages as to the connection between the igneous phenomena and the faulting in the Glencoe area.

Carboniferous. Carboniferous rocks have been surveyed in South Wales, Derbyshire and the Midland Valley of Scotland. The detailed mapping of the Carboniferous Limestone series in Pembrokeshire has brought out certain interesting features. On the north side the zonal sequence is defective. The lower division of the series, for which Dr. Vaughan has proposed the term Clevedonian, is here represented only by the upper part of the *Cleistopora* zone, the lower part including the *Modiola*-phase being absent or represented by a few feet of coarse sediment. Another break occurs on a higher horizon. Thus at one point the Upper, or Kidwellian, division, according to Dr. Vaughan's nomenclature, is represented by a dark limestone belonging to the *Seminula* zone and containing inclusions of a grey limestone, with fossils indicating a horizon, probably not higher than the lower part

* On the Metamorphic Rocks surrounding the Land's End mass of Granite. *Quart. Journ. Geol. Soc.*, Vol. XXXII. (1876), p. 407.

† The Igneous and Altered Rocks of south-west Devon. *Trans. Devon. Assoc.* Vol. XIX. (1887), p 467.

‡ Mitth. über dem Granit des Dartmoor Forest und einige seiner Contactgesteine. *Neues Jahrb. Beilage*, Band XIII. (1899–1901), p. 90.

of the *Zaphrentis* zone. There is evidence, therefore, of two breaks in the faunal sequence on the north side, and of the presence of something like an unconformability in the middle of the series. Carboniferous.

On the south side of the coal-field a different state of things has been noticed. The sequence is complete; but some of the strata which are absent in the north are here in the condition of dolomite. Moreover, the dolomitization, while remaining practically constant from east to west, increases from south to north, so as affect a greater vertical thickness of beds. If shallow water is favourable to dolomitization, as appears to be the case, this state of things would indicate an approach to shore-conditions as we proceed from south to north; and this is in accordance with the evidence as to the existence of a palæontological and physical break on the north side of the coal-field.

The features of greatest interest in relation to the Millstone Grit and Coal-measures of Pembrokeshire are structural. In no other coal-field in the British Isles have the rocks been so powerfully affected by earth-movements; and, in view of the enormous complication, it is a most fortunate circumstance that in our attempts to unravel the structure we have not only the surface outcrops and old workings to aid us, but also a magnificent coast-section extending right across the syncline from Gilman Point to Tenby.

The general results are so well summarised in the following pages that I will only refer to one point of great interest, both from an economic and from a scientific point of view. In a portion of the coal-field where the surface rocks show intense disturbance and where the coal seams as well as the strata with which they are associated are broken up by innumerable small folds and overthrusts, the lower measures are comparatively undisturbed, and certain coal-seams which occur in them are now being worked at a depth of 150 yards: "of the innumerable folds and thrusts observable on the surface not one in fifty exists at that depth."

Passing now to the Midland District we have to note results that will involve a considerable change in the geological map of the western border of the Derbyshire coal-field. On the old map the Coal-measures are represented as being cut off from the older Carboniferous rocks by a north and south fault, the so-called Trinity Chapel fault; but the detailed mapping on the six-inch scale has proved that this fault does not exist. Some part of the area represented as Coal-measures on the old map will, therefore, have to be relegated to the Millstone Grit, and our ideas as to the structure of this part of the coal-field will have to be radically changed. One result of this work has been to connect up the anticlines of Ashover and Crich. (See Fig. 1, p. 17.) The accurate knowledge that we now possess of the structure of this district may prove of value in relation to coal-mining and water supply.

Carboniferous. In the areas occupied by Coal-measures in Derbyshire the principal work has consisted in tracing the outcrops of the different sandstones which form a reliable guide to the surface position of the various coal-seams, and also serve to bring out the general structure of the coal-field. Careful attention has also been paid to the vertical distribution of fossils in the productive measures. The work of Messrs. Hind and Stobbs in North Staffordshire has proved the value of this line of investigation, in correlating coal-seams over extensive areas; and there is good reason to believe that it will prove to be of equal value in the Nottinghamshire and Derbyshire coal-field. The point is one of great importance in connection with the development of the concealed part of the coal-field, because conclusions of great moment have frequently to be drawn from the meagre evidence supplied by bores. It is sincerely to be hoped that all those who put down deep bores in search of coal or water will allow the cores to be examined by experts who are thoroughly qualified to form an opinion as to the horizons of the measures passed through.

The revision of the carboniferous areas in the Midland valley of Scotland, in the Glasgow, Airdrie and Charlestown districts, will result in the increased accuracy of the survey maps and the addition of further detail. This will be due almost entirely to the extensive workings for coal and fireclay that have taken place since the earlier survey was carried out, and the readiness with which all those who are engaged in exploiting the mineral wealth of the district have placed their information at our disposal.

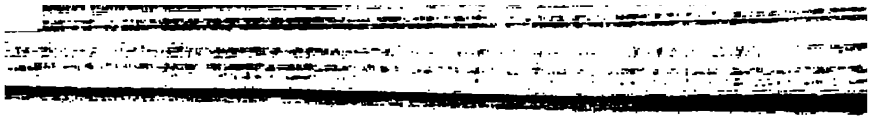
Trias with Rhætic. But little work has been done during the year on Mesozoic or Cainozoic rocks. A small area occupied by Trias with Rhætic has been surveyed between Nottingham and Newark, and the boundary lines have been laid down on six-inch maps for the first time. The more detailed survey will not involve any important modifications in the lines of the one-inch map; but slight changes, due to the fact that the tea-green marls are now classed with the Keuper instead of the Rhætic, will have to be made.

Lias A small area of Lower Lias has been surveyed on the eastern margin of Sheet 126.

Pleistocene and Recent. In all districts where work is in progress careful attention is being paid to the superficial deposits, and much information with reference to them will be found in the following pages. Amongst the more interesting features of this work may be mentioned the recognition of a comparatively driftless area in Nottinghamshire, separating the eastern from the western drifts, and the evidence that the basin of Loch Monar in Ross-shire marks the position of a centre of ice dispersion during the period of maximum glaciation.

In addition to the field operations much work has been done in the palæontological, petrographical and chemical departments

In the Museum progress has been made with the preparation of an exhibit illustrative of British Clays, and the important series of road-making stones on which attrition tests have been made by Mr. Lovegrove, Engineer to the Hornsey Borough Council were arranged for exhibition. These stones have been examined petrographically by officers of the Museum and Survey, and the general results of the combined work of these officers and Mr. Lovegrove are recorded in the following pages. Museum.



I.—ENGLAND AND WALES.

I.—FIELD-WORK.

The ground to be surveyed was arranged in four areas as follows:— Mr. Woodward.

1. Midland district under Mr. G. W. Lamplugh.
2. Southern district under Mr. C. Reid.
3. South Wales district under Mr. A. Strahan.
4. Supplementary district under Mr. H. B. Woodward.

In the Supplementary district the field-work necessary for the completion of the special map, with Oxford as a centre, was brought to a termination. Mr. Woodward personally surveyed a portion of the ground, but the greater part was done by Mr. T. I. Pocock. As the MS. of the memoir in explanation of the the map has been completed, it is unnecessary here to give any particulars of the field-work which consisted largely of the survey of disconnected tracts.

In addition to the ordinary field-work Mr. Woodward visited Southwold to examine the evidences of recent erosion of the coast. Mr. G. Barrow further examined cuttings on the Great Central Railway near Gerrard's Cross west of Uxbridge, he visited the excavations for the Rotherhithe tunnel, and several of the Tube railways in progress, gathering and tabulating much geological information.

The examination of the cuttings on the Clarbeston and Goodwick Railway, begun by Mr. H. H. Thomas in 1904, was continued by him in 1905.

In addition to the ordinary field-work Mr. W. Gibson examined the rocks from the shaft-sinkings and deep-borings in progress at Claverley, Langley Green, Mansfield Colliery, Manton Colliery, Bentley Colliery, and Selby; and Mr. C. B. Wedd examined those from the Kilburn and Oakerthorpe Collieries.

Mr. T. C. Cantrill inspected some new excavations in the Coal-measures near Nuneaton, and obtained important information respecting recent borings.

1.—Midland District—Derbyshire and Nottinghamshire.

Mr. G. W. Lamplugh, F.R.S., District Geologist.
Mr. W. Gibson, B.Sc.
Mr. C. B. Wedd, B.A.
Mr. W. B. Wright, B.A.
Mr. R. L. Sherlock, B.Sc.
} Geologists.

The Trent Valley and contiguous area between Nottingham and Newark.

During the year the survey of Sheet 126 was completed, and as the map and memoir are now in course of preparation, only a brief outline is given of the results obtained. The country examined during the year includes a large part of the Vale of Mr. Lamplugh, Mr. Wright, Mr. Sherlock

Lamp- Trent between Nottingham and Newark with some of the rising
h, Mr. ground bounding it on the north-west and a wider tract of
ght and similar ground on the south-east, extending two or three miles
Sher- across the tributary valley of the Devon River, up to the eastern
. edge of the map.

TRIAS.

The steep river-cut bluffs on both sides of the Trent below Nottingham are composed of Keuper Marl containing thin sandy layers locally known as "skerry." North of the river the more sandy beds, known as Waterstones, which form the base of the marls, are exposed in the valleys of most of the tributary streams; but under the influence of the general south-easterly dip of the Trias these beds pass beneath the surface in the Trent valley above Thurgarton, and are not seen south of the river.

In the upper part of the Keuper Marls south of the Trent, besides the more or less impersistent skerry bands, which have been mapped where possible, Mr. Wright has been able to trace for some distance, south and east of Bingham, a belt of sandy material which has a marked effect upon the character of the soil at its outcrop. Above this bed most of the Keuper Marl is free from sand or "skerry." The belt of nearly pure marl extends to the base of the Rhætic, and contains some massive beds of gypsum, evidently of contemporaneous origin.

The mapping of the "skerry" bands, which usually form a protective capping to low hills of marl, has clearly demonstrated the very gentle dip of the strata, and serves to bring out the structure of the country.

Rhætic.

The black or dark grey marine shales of this formation which mark the transgression of the open waters of the sea towards the close of Triassic time form a narrow continuous belt bordering the Keuper tract south-east of the Trent. These shales outcrop along a well-defined slope beneath the basal limestones of the Lias. The only clear section of the Rhætic beds at present visible in the district is at the Beacon Hill brickyard on the eastern outskirts of Newark. The section shows the Lower Rhætic only, and it is interesting to note that the "Bone Bed" is absent. A slight modification of the previous one-inch map became necessary owing to the inclusion of the "tea-green marls," immediately underlying the black shales, with the Keuper Marls instead of with the Rhætic.

LIAS.

Wright The Lower Lias which occupies a broad strip within the
Mr. eastern margin of the new map forms an undulating tract of
lock. clay-land, slightly ridged by minor features marking the outcrop of thin limestone-flags. These limestone-bands have, as far as possible, been traced on the six-inch map.

PLEISTOCENE.

Glacial Drift.

Considering the great development which the glacial deposits attain in neighbouring tracts to the west, south, and south-east, there is surprisingly little evidence of glaciation over a large part of the country included in Sheet 126; and the remnants that occur are the more difficult to explain because of their scantiness. It is probable that within the limits of this map we have to deal with traces of the fringing deposits of both the eastern and the western ice-sheets, which appear to have skirted the district but to have actually covered only a portion of it, the western drift extending southward along the Leen valley, and the eastern drift reaching its termination near the south-eastern margin of the district, thus leaving the greater part of the dissected Triassic plateau north of the Trent apparently unglaciated. Mr. Lamplugh, Mr. Sherlock a Mr. Wrigh

The drift of the Leen valley consists mainly of patches of gravel, occurring at varying elevations on the slopes and occasionally even on the crest of the valley (*e.g.* at Bestwood Lodge), composed chiefly of material derived from the Bunter but including also a few boulders of Carboniferous sandstone and rarer blocks of andesite and other far-transported blocks probably from the Lake District. The drift found south of the Trent, consists partly of gravel and partly of stony clay, in which flints are usually, though not invariably, abundant.

The driftless areas are remarkable for the regularity with which atmospheric erosion has developed strong surface-features from every hard band, even when of insignificant thickness. The same characteristic is also observable in those areas where the drift is very thin; but in places where it attains a thickness of 4 or 5 feet this regularity of sculpture is at once broken up.

East of Nottingham, the only place north of the Trent in which any trace of glaciation was observed is in the valley of the Greet between Southwell and Fiskerton, where the Southwell main-drainage trenches have recently shown the disturbed Keuper Marl to be irregularly covered with patches of stony loam, containing a few small blocks of Carboniferous sandstone, and a boulder of basalt, like Derbyshire "toadstone," a foot in diameter. This may imply the passage of a small tongue of ice southward along the Greet valley.

Trent Alluvium.

The chief post-glacial deposits of the district are the thick masses of river-gravel and alluvium which cover the broad floor of the remarkably straight-sided trench in Triassic strata, averaging about two miles in width, along which the Trent flows between Nottingham and Newark. It is probable that the accumulation of this material commenced at the time when the river was periodically swollen by flood-waters from the waning ice-sheets, and that the highest gravels, such as the curious Gamston ridge on the southern side of the valley between West Bridgeford and

Mr. Lamplugh, Mr. Sherlock and Mr. Wright.

Radcliffe referred to in last year's Summary, are of late-glacial rather than of post-glacial age. But even subsequently to this high-level stage the river must still have continued for a long time greatly to exceed its present volume, as it has spread out great sheets and bars of gravel over the whole breadth of its trench, amid which its present channel winds to and fro, considerably above the original bottom of the valley. In this part of its course the Trent itself appears to have made very little addition to the alluvium of its flat during the later stages of post-glacial times. There has, however, been much material brought down by its small tributaries and deposited along the margin of the main valley-floor, in the form of delta-like spreads of red loam or clay mostly derived from the Keuper beds.

The principal masses of gravel and sand of the Trent flats below Nottingham are not arranged in successive terraces, but in slightly raised belts and broad low spits usually elongated in the direction of the valley. These have probably been rapidly accumulated under a definite set of conditions when the slackening river was bringing down more load during its floods than it could shift during the rest of the year, and was consequently burying up its previously excavated valley. During this stage the river seems to have spread across the whole width of its valley-floor, probably dividing into numerous branches that were constantly swinging and changing their courses.

The low undulations of the gravel flat thus formed have since been partly obliterated by the clayey sediment brought down by the side-streams to which reference has been already made. This clay or loam is usually several feet thick around the mouths of the small valleys, and spreads outward from them in broad fans which thin off gradually above the gravel, as may be well seen opposite the confluences of Cocker Beck, Dover Beck, and the River Greet with the main valley. In other parts of Trent flats, which were sheltered from these red clayey sediments by intervening bars of gravel, there have been local accumulations of stiff grey mud containing much vegetable matter and thin seams of peat, which also tend to fill up the original inequalities of the gravel-floor. The alluvial deposits of the Trent valley thus give rise to soils that vary greatly in their agricultural properties in different places; but, as the drainage trenches recently opened on the Nottingham sewage farm between Stoke Bardolph and Gunthorpe have shown, these variations occur so irregularly and indefinitely that in the absence of such artificial sections they could not be traced in detail on the map.

South and south-east of Newark there is a great development of sand and gravel, which is believed to mark an ancient course of the Trent leading eastward toward the Lincoln Gap. But as these deposits have been fully discussed by Mr. A. J. Jukes-Browne in a previous Survey Memoir ("Geology of the South-West Part of Lincolnshire") and as only the fringe of the gravels has been reached in the present map it is unnecessary to refer further to them.

Other Alluvial Deposits.

The red loamy clay that lines the margin of the Trent flats as above described is continuous with similar material that deeply covers the floors of the smaller tributary valleys. In the flatter parts of the valley-floors this alluvium has sometimes a thickness of 8 or 10 feet, as for example in the middle reaches of Halloughton Dumble and along the Cocker Beck below Lambley, and is remarkably homogeneous and unstratified, often presenting a loess-like structure. The present streams have cut deep narrow gullies through this deposit, revealing at the base a rubble of local origin associated with sandy and gravelly layers containing mammalian bones and plant remains. A local bed of marly alluvial mud which accompanies these sandy and gravelly deposits in Cocker Beck yielded abundant land and freshwater shells. The collections made by Mr. Wright from this fossiliferous layer in Cocker Beck and Halloughton Dumble show that the deposit cannot be of earlier date than Neolithic, and therefore that the overlying unfossiliferous loam, in spite of its thickness and its apparent antiquity in relation to the present stream-courses, has been very recently deposited. The mammalian remains consisted of bones of horse, ox, pig, sheep or goat, and dog or wolf. Traces of man, including a human femur peculiarly compressed at the upper parts, and a small worked flint, were also found. The ox remains are small and may belong to *Bos longifrons*. Mr. Lamplugh, Mr. Sherlock, Mr. Wright

The greater part of the country south-east of the Trent drains eastward into the Devon, and in connection with this drainage-system there are extensive alluvial flats. Some of these, such as that at Bingham, exhibit under a thin covering of peaty loam considerable areas of white shell-marl, showing the former presence of large sheets of still or sluggish water.

ECONOMIC GEOLOGY.

Gypsum.—The Gypsum deposits of the neighbourhood of Newark are amongst the most valuable in this country and have been worked for a long time. Gypsum occurs at intervals throughout the Keuper Marls, but the chief deposits occur at an horizon only a few feet below the "tea-green marls" which themselves are immediately overlain by the Rhætic Beds. The Gypsum is found in bands usually ten inches or a foot in thickness alternating with a few feet of red marl. There is evidence that the gypsiferous strata cover an extensive area, and that with an increased demand the industry would be capable of still more extensive development. Gypsum beds on the same horizon are also extensively worked at Cropwell Bishop and were formerly mined at Orston. Massive lenticles of Gypsum were observed on this horizon at various other places, and tend to show the continuity of this series of deposits within the limits of the map. Mr. Sherlock. Mr. Wright

Bricks.—The Keuper Marls afford an unlimited supply of clay useful for bricks, but it is not much worked. The brickyards generally occur in connection with the gypsum works, as the quarries for the latter mineral provide brick clay as a w[redacted] Mr. Sherlock.

. Sher- product. Even in this case, however, it is not found possible to
r. utilise the whole of the clay owing to the lack of profitable markets for the product.

Flags.—The lowest beds of the Lias consist of compact beds of limestone, usually three to four inches thick, separated by sandy shales. These limestones have been used as flagstones, and at one time were in demand for the paving of barn floors. The jointing permits of large flags being raised, but the trade has practically died out since the railways have brought in the competition of better known flagstones and artificial paving-slabs. Locally the limestones are also used for macadam and building walls.

East Derbyshire: Western District (Matlock, Wheatcroft and Wessington).

Wedd. The area mapped consists chiefly of a small tract of Coal-measures in the neighbourhood of Wessington and Brackenfield, and of Millstone Grit between Wheatcroft and Matlock Moor; also of a strip of Millstone Grit, Limestone Shales, and Carboniferous Limestone along the southern margin of Sheet 112.

Carboniferous Limestone. A little further evidence has been obtained of the toadstone outcrops in the neighbourhood of Middleton, but the completion of the zonal examination of the limestone remains to be done. The corals and brachiopods show that the bulk of the limestone of the district—at least down to the Second Toadstone—belongs to the Upper *Dibunophyllum* zone (D2) of Dr. Vaughan's classification.

Limestone Shales. Very little has been seen of these strata.

Millstone Grit Series. The upper or main Kinderscout Grit is found to split into two beds separated by shale west of the Ashover Valley.

A bed of very coarse-grained pebbly grit is developed on Matlock Bank a short distance above the coal which overlies the Kinderscout Grit. This upper coarse grit is met with in the Derwent Valley Waterworks tunnel. Messrs. Drabble and Williams, engineers of the Derwent Valley Water Board, have noted the apparent occurrence of detrital garnets in this grit. We have been able to confirm this in specimens from the tunnel on Matlock Bank.

North of Crich the Kinderscout Grit can be traced continuously as a coarse-grained and somewhat pebbly rock, round the north end of the Crich limestone, and along the east side of the latter, until a fault cuts it off at Culland Wood. Green regarded this grit east of the limestone as the Rough Rock or Top Grit, separated from the limestone by a continuation of the "Trinity Chapel Fault."* It will be shown below that the introduction of this fault was due to a mistaken reading of the ground.

*"The Geology of the Carboniferous Limestone, etc., of North Derbyshire" (*Mem. Geol. Surv.*) Ed. 2, p. 84 (1887).

Thus the Kinderscout Grit has an anticlinal V-shaped out- Mr. Wedd.
crop pointing north and marked by an unbroken dip-slope.

The outcrops of the lower of the Middle Grits converge northward around this feature and meet at Lindway Lane. From here to Dochole this rock remains undivided in a broad saddle extending across the line of the "Trinity Chapel Fault," and bends down abruptly eastward. It has the usual fine-grained and somewhat micaceous character of the Middle Grits in this neighbourhood and further south.

North of it the Kinderscout Grit emerges again with a V-shaped outcrop pointing south. Running south-east with gentle south-westerly dip on the lofty ridge of Highoredish, it bends over sharply eastward and continues northward in a steep bank of lower elevation behind Trinity Chapel, but is not cut off by a fault. It completely encircles the Ashover Valley (See Fig. 1).

Below it, and above the south end of this valley, a small fine-grained grit, the probable representative of the lower Kinderscout Grit of the neighbouring district on the south-west, bends over eastward in the same way.

East of the line of the "Trinity Chapel Fault," the higher rock of the Middle Grit Group, fine-grained as usual, succeeds the lower member of the same group, and can be traced continuously.

The Rough Rock or Top Grit follows it, but is only exposed at intervals. In the borehole of the Alfreton Waterworks at Lindway Springs it is more than 100 feet thick, and is well displayed in the banks of the No. 2 Reservoir. It has become a finer-grained rock similar to the Middle Grits, and has lost the coarse and somewhat pebbly character it maintains as far north as Ridgeway (Sheet 125).

Thus no part of the Millstone Grit sequence is missing on the east side of the supposed fault-line. Neither is any part of the lowest Coal-measures cut out. In fact the shallow folds into which these measures are thrown might suggest the presence of a greater thickness than is actually represented. All the sandstones of these measures in this district are distinguishable by texture and colour from the Millstone Grits.

It will be shown further that a powerful north and south fault would be at variance with the structure of the ground.

Coal-measures. The outcrops of the Rough Rock and the Wingfield Flagstones diverge northward and converge again in a striking manner. They thus enclose between South Wingfield, Wheatcroft, and Brackenfield, a roughly oval area composed entirely of the lowest Coal-measures below the Wingfield Flagstones. The exceptional width of this tract, about one and a half miles, is due to shallow folding of a local nature (Fig. 1).

The cutting of the Ambergate and Pye Bridge Line, north of Ridgeway (Sheet 125), shows thick sandstones with shaly partings in the lowest 300 feet of the Coal-measures. These sandstones seem to have split up by intercalation of shale into thin beds, some of which may have passed laterally into gannister in the ground under description.

Mr. Wedd

The bulk of these lowest measures here consists of soft shales with thin sandstones, beds of gannister, and more than one small coal-seam. But higher beds below the Wingfield Flagstones contain thicker beds of gannister, with which is associated a valuable pottery clay, now worked west of Wessington Green.

A little higher a coal-seam has been dug on Wessington Green, below a thin sandstone on the dip-slope of which the Green is situated. The roof of the coal contains *Pterinopecten papyraceus*. In apparently the same stratigraphical position, at the stream in the north-west part of Ogstoncarr Wood, black shale with calcareous nodules is associated with a coal-seam and contains *Gastrioceras* (*G. carbonarium* ?) and *Pterinopecten papyraceus*. We may thus expect that the associated coal will prove to be the Alton, though it has not yet been ascertained whether it has the usual floor of gannister. It seems to lie at about the normal distance below the Wingfield Flagstones. The great interval separating its outcrop at Wessington from that of the Rough Rock is of course due to the folding mentioned above.

The succeeding measures up to the Wingfield Flagstones consist of shales with numerous small sandstones and beds of gannister and a one-foot seam of coal in the lower part.

The Wingfield Flagstones lose their characteristic feature at Wessington, where they produce several smaller ridges by the intercalation of shale. They however recover their usual bold escarpment at Ogston Hall. The rock above the Tupton or Furnace Coal increases, and becomes the dominant feature of the neighbourhood.

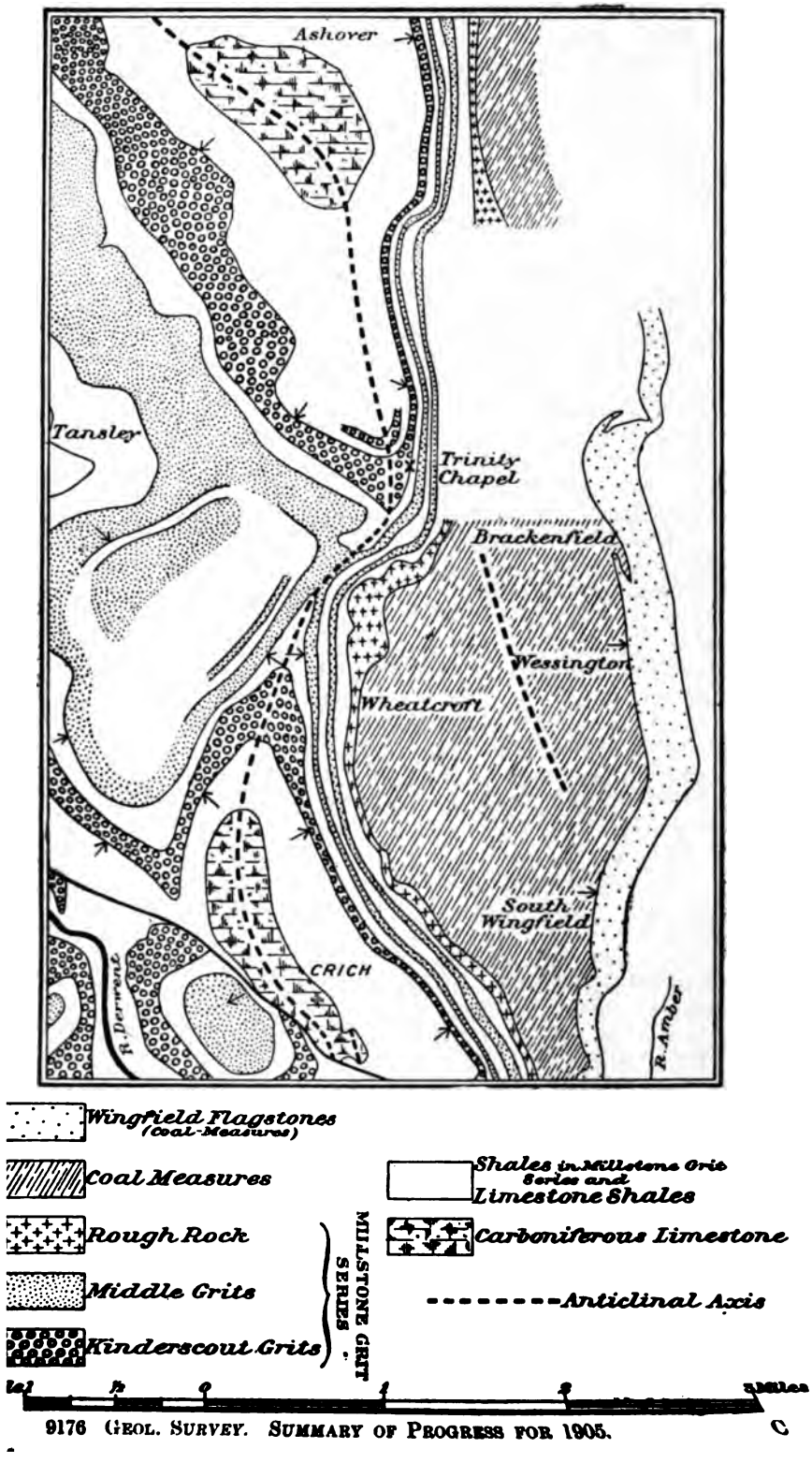
At the Kilburn Colliery (Sheet 125) a new shaft is being sunk below the Kilburn Coal. It is hoped that this will definitely prove the value of the lower coals and the thickness of their measures, which are almost unexplored by shafts. It has already passed the Alton Coal, recognised by the marine fossils of its roof and its floor of thin gannister, at a depth of 574 feet below the Kilburn Coal. An effort is being made to secure all available palæontological evidence from this shaft, and much trouble has been taken by the colliery officials to obtain and catalogue specimens.

Structure of the Ground.—An anticlinal fold trending northward first becomes recognizable south of Belper (Sheet 125). This fold increases gradually in strength and elevation to Crich, where it is intersected by the Southern Crich Fault. Beyond this the anticlinal axis in the limestone runs at first north-westward, but swerves to north before passing out of the limestone at the surface.

The recent mapping of the neighbouring part of Sheet 112 has shown clearly that this anticline is continuous with that of Ashover, and runs in a sigmoid curve from the south end of the Crich limestone through that of Ashover (Fig. 1).

The line of the anticlinal axis, after leaving the Crich limestone, and swerving from north to north-north-east, can be traced successively in the Kinderscout Grit, in the lower of the Middle Grits, beyond which it bends north, in the Kinderscout

FIG. 1.—*Sketch Map of the Country between Crich and Ashover.*



Mr. Wedd. Grit again, in the lower Kinderscout Grit, and in the Ashover limestone, where its course has changed gradually to north-west.

Between Crich and Ashover the saddle varies in elevation, and is lowest between Lindway Lane and Doehole. Hence a bed crossing it south and north of these localities will have V-shaped outcrops pointing north and south respectively.

The points of greatest elevation in the saddle are of course in the limestone of Ashover and Crich. The altitude of any given stratum in crossing the anticline at its lowest elevation between Lindway Lane and Doehole may be estimated roughly at 800 feet less than the altitude of the same stratum in a similar position at Crich, and 600 feet less than at Ashover.

From Crich northward the dip of the eastern limb of the anticline increases and becomes very steep where the saddle is lowest, but diminishes again before reaching Ashover Hay. On the west a high dip is found only in the neighbourhood of the Southern Crich Fault and on its north side. This is probably owing to a downward drag in the fault and a slow recovery northward.

It will be seen that this anticline conforms closely in its curves to the outline of the anticlinal south-eastern spur of the Derbyshire limestone massif, from which it is separated by a shallow syncline. It is evident that this long curving anticline and its complementary syncline, bending round the end of the anticlinal spur of the limestone massif, are the effect of the elevation of the latter, which has wrinkled the neighbouring strata. This is confirmed by the manner in which the long sinuous wrinkle resumes the general southerly strike, before dying out and after passing beyond the influence of the anticlinal limestone massif.

East of the saddle of Crich and Ashover the lowest Coal-measures are thrown into folds. Thus a depressed plain bounded by higher ground and trenched on its north-east side by the valley of the Lindway brook, occupies a syncline extending from Moorwood Moor to Lindway Lane. This syncline is practically a closed basin. A broad ridge of higher ground on its east side trends north-north-west and merges northward into a plateau at the foot of the dip-slope of the Kinderscout Grit. The ridge is mainly anticlinal, and owes its existence to the elevation of hard sandstones and gannister beds, while a valley has been excavated in the soft shales of the syncline on the west. This elevation, however, is not a simple anticline, but includes at least one small and sharp synclinal fold. Higher beds dip steadily eastward away from it.

It will be noticed that these local folds lie in juxtaposition with the lowest and steepest elevation of the Ashover and Crich anticline, as though the force which wrinkled up the latter had not spent itself, but had found relief in the production of smaller folds further east.

It is plain that if a large north-and-south fault passed by Trinity Chapel, it would ignore the structure of the ground, and could only belong to a system of dislocations later than the production of this structure.

The closed synclinal basin of Moorwood Moor suggests that a boring in the middle of it would tap all the water accumulated in the Millstone Grits of the neighbourhood, east of the Crich and Ashover anticline. But the narrowness of the grit-outcrops and the consequent smallness of the collecting ground would militate against an abundant supply. Mr. Wedd.

Chesterfield and District.

COAL MEASURES.

Stratigraphical.—The chief work has consisted in tracing the outcrops of the different sandstones which occur in association with the various coal seams. These form a most reliable guide to the surface position of the latter, and also serve to bring out the general structure of the area. At the present day mining operations do not extend below the horizon of the Black Shale or Silkstone Coal; it may therefore be expected that when the lower seams come to be worked the map will form a useful guide. Mr. Gibson.

In the summaries for 1902–03 it was stated that the sandstones below the Top Hard Coal, with the exception of the Kilburn rock, were feebly developed and impersistent in character throughout the Erewash Valley. On crossing the watershed into the Rother drainage system it has been found that these sandstones increase in thickness and become more persistent, though still inferior to those of the Yorkshire Coalfield.

The following table will give the position of these sandstones and their associated coals with their probable Yorkshire equivalents:

Chesterfield.	*S. Yorkshire.*
Top Hard Rock	Barnsley Rock
Top Hard Coal	Barnsley Coal
560 feet	560
Thin Sandstones	Bordwell and Thornhill Rock
Deep Soft Coal	Flockton Coal
175 feet	240
Deep Hard Rock	Park Gate Rock
Deep Hard Coal	Park Gate Coal
190 feet	
Tupton Coal	
180 feet	300
Black-shale Rock	Silkstone Rock
Black-shale Coal	Silkstone Coal
450 feet	
Kilburn Rock	
Kilburn Coal	
50 feet	
Wingfield Flagstones	

The Wingfield Flagstones can be traced continuously from east of Stretton to Hardwick Wood, where a fault shifts the outcrop westward. As the Kilburn Coal has not been tried around Clay Cross or Chesterfield, the Wingfield Flagstones should prove of use in identifying its outcrop and probable depth over the unmined areas. The question whether its equivalent can be recognised in Yorkshire must await the examination of the ground between Chesterfield and Sheffield.

Mr. Gibson. The Black-shale rock is very impersistent, but with a tendency to increase northwards, though never becoming a massive rock.

In the Stretton area a sandstone varying from a fairly massive grit to a thin-bedded laminated rock lies a few yards above the Tupton or Furnace Coal, and forms a prominent ridge from Stretton to Clay Cross. It dies out northward, but as it does so another above the Deep Hard Coal gradually assumes importance, and at Wingerworth and thence northward distinctly indicates the position of the Deep Hard Coal.

The sandstone above the Deep Soft Coal commences a little south of Chesterfield and increases in thickness northward.

The Top Hard rock is rather a series of beds and sandstone with partings of shale of varying thickness than a continuous sheet of massive rock. The group, however, universally gives rise to a well-marked feature.

Structural.—Between Morton and Spital Brook the measures have a general easterly or north-easterly gentle inclination. The rarity of faults is remarkable, such as occur resolving themselves into two main belts of dislocation which, though they have a general north-north-west and south-south-east trend, in the Chesterfield area have a more nearly east and west direction. The southernmost, of only a few yards' throw, crosses the brick-pits near No. 2 Colliery of the Clay Cross Company. It has little effect in disarranging the regular trend of the outcrops. The northernmost is a composite fault, made of several minor faults, but with an aggregrate throw to the north. It can be traced continuously from North Wingfield to Stubbing Court. As previously stated (p. 19) it exerts a powerful effect on the outcrop of the Wingfield Flagstone. Between these localities and northward to Hasland the ground is unbroken and the general easterly dip is maintained.

North of Spital Brook the strata rise up into a sharp and well-defined anticline the axis of which trends nearly north and south along the high ground of Calow and Brimington Common. The southern termination is intersected by the Lancashire, Derbyshire, and East Coast Railway, of which the sections have been described by Mr. Fox Strangways (*Quart. Journ. Geol. Soc.*, Vol. liv., pp. 163–167). To the south-east the anticline sags down and is succeeded in this direction by a syncline, but of a less defined character. A similar syncline occurs on the western side of the anticline. On the south these folds terminate against a well-defined fault varying in direction from north-north-west to north-west and south-east and traceable from Cutthorpe to Temple Normanton.

Palæontological.—While the production of a geological map showing the main outcrops and the structure of the area has been the chief object in view, attention has also been paid to the palæontological character of the strata, in the hope that the evidence yielded by the fossils will prove of service to the miner in sinking for coal within and beyond the known eastern extension of the Nottinghamshire and Derbyshire Coalfields underneath the red rocks. The varying character of the Coal-measure

sequence and the lithological similarity of the rocks comprising the productive portion have rendered the correlation of the different seams, even within the highly explored coalfield, a difficult task. How much more must this be the case when Coal-measures are penetrated beneath the Permian and Triassic rocks, in areas far removed from known workings, owing to the strong unconformity at the base of the red rocks? It is here uncertain if a boring has reached an horizon high up or low down in the productive measures, for although certain lithological characters form safe guides for the identification of portions of the upper unproductive measures (Summary, 1904) they fail in the case of the productive measures, and it is the latter which underlie the greater part of the Permian and Trias of Nottinghamshire. As to the extent to which the fossils will assist us, it appears, from the examination of the Coal-measures in Derbyshire and Nottinghamshire during the re-survey, that certain fossils may be as safely used in the identification of horizon in the sequence, as has been shown to be the case by Messrs. Hind and Stobbs in N. Staffordshire. It is perhaps too early to assert that this is positively assured for the whole of the great coalfield on the east side of the Pennines. To the determination of this question it is highly desirable that the efforts of local geologists and mining men should be directed, as more extensive research can alone give definiteness to what for the present must be considered as hopeful signs of ultimate success. Mr. Gibson.

The following horizons certainly hold good for the area so far examined, which may be taken as covering about 100 square miles.

A. Zone of Anthracomya Phillipsi.—This fossil is entirely confined to the measures above the Top Hard or Barnsley Coal. It first appears above the High Hazle Coal, 210 to 250 feet above the Top Hard, but is constant and most abundant at 700 to 900 feet above the Top Hard.

B. In the Summary for 1902 (pp. 14 and 15) a bed with *Lingula, Discina*, and *Acanthodes Wardi* was recorded from the Gedling Colliery at 524 feet above the Top Hard. At Sherwood Colliery, Mansfield, a bed of blue bind (blue shale) with a dark blue argillaceous ironstone weathering to a buff brown colour yielded *Lingula* and *Discina* at 730 feet above the Top Hard. In examining the new sinking of the Mansfield Colliery, three miles east of the Sherwood Colliery, a bed of blue clunch with a similar band of dark blue ironstone, evidently on the same horizon, lying 630 feet above the Top Hard Coal, contained a rich marine fauna (see p. 76).

This shows the closest resemblance with the marine fauna below the Gin Mine in N. Staffordshire.*

The differences in position at Gedling, Sherwood, and Mansfield are in conformity with the general thickening northward and the general decrease in thickness eastward. It is interesting to note that in the boring at Thurgarton 5½ miles north-east

* John T. Stobbs. *Quart. Journ. Geol. Soc.*, vol. lxi., 1905, p. 501.

Mr. Gibson. of Gedling and 11 miles south-east of the Mansfield Colliery a marine bed with *Chonetes laguessiana, Lingula mytiloides, Productus* sp. was detected at 560 feet above the bottom of the boring. The same horizon was no doubt passed through at the Manton Collieries, Worksop, and in the Bentley Boring, near Doncaster, but its identification awaits accurate confirmation.

C. Horizon of the Dunsil Coal.—Continuing the sequence downward, there is hope that a bed, rich in Lamellibranchiata, noted by Mr. E. Bingley, manager of the Mansfield Colliery, will also prove a useful horizon. This bed forms the roof of the Dunsil Coal, 63 feet below the Top Hard Coal. It contains an assemblage of estuarine shells (see p. 78), which appear to be constant at this horizon though not determined with certainty. If so, beds B and C will serve to fix the position of the Top Hard with considerable definiteness.

D. Horizon of the Deep Soft Coal.—In the Summary for 1902, p. 15, notice was made of the occurrence of marine fossils in an undetermined position below the Top Hard, during the widening of the Midland Railway 300 yards north-west of Padley Wood. This horizon has been fixed during the past year as occurring 300 feet above the Deep Hard Coal, and about 500 feet below the Top Hard. It has again been found in position in the railway-cutting east of Duckmanton, but at a somewhat greater distance above the Deep Hard Coal in accordance with the general northerly increase in thickness. The fossils include Goniatites, *Myalina, Pterinopecten, Productus.*

E. Horizon of Carbonicola robusta.—This fossil still appears to be restricted to a thick horizon occupying a position between the Deep Hard and Kilburn coals (Summary for 1904, p. 11).

F. Horizon of the Alton Coal.—This coal is unquestionably on the same horizon as the Crabtree Coal of North Staffordshire. In each the same species of Goniatites are met with in the roof of the seam. In addition, species of *Pterinopecten, Productus, Spirifer, Orthoceras* are not uncommon.

GLACIAL.

Around Chesterfield and the district to the south glacial deposits are absent. Not only is there no sign of boulder clay, sand, or gravel, but not a single foreign pebble or boulder has been met with. The frequent occurrences of wide areas of bare unweathered rock appears, however, to indicate that some scouring agency has affected the district during or since glacial times.

ALLUVIUM.

As the streams possess a high grade, the alluvial deposits consist for the most part of coarse gravels forming a narrow irregular fringe along the stream margins. The absence of pebbles or blocks of foreign origin in the gravels confirms the conclusion that the region was never covered by glacial deposits.

ECONOMIC GEOLOGY.

Brick-clays.—Apart from its favourable situation in a district whose population is steadily on the increase, and from its being within easy railway communication with the mining towns and townships so rapidly springing up to the east situated within the newly developed coalfield, Chesterfield possesses distinct geological reasons why it should have become the centre of a clay industry. Suitable building stones are absent, while beds of clay abound. The latter also occur in a particularly favourable manner, whose chief characteristics may be tabulated thus: Mr. Gibson.

1. Presence of thick beds of clay with few or no bands of waste rock.
2. Variety of material.
3. Proximity to seams of quick-burning coals.
4. Absence of superficial deposits.

1. Beds of clay, varying from 10 to 20 feet in thickness, occur on several horizons between the Top Hard and Silkstone coals. The intercalated sandstones seldom exceed the total of a foot in thickness.

2. Clays for the production of either a red or blue brick occur; while north of Clay Cross, more especially in the vicinity of Chesterfield, the under-clay of the Tupton Coal yields a good pottery clay. It, however, has a tendency to pass laterally into a gannister.

3. In many clay-pits the workable clays overlie seams of coal which can be used in the kilns.

4. In all the clay-pits the material from the surface down to the floor of the excavation can be made use of.

Water Supply.—As in other mining districts, an extraneous source of supply has to be relied on. Chesterfield and Clay Cross obtain their water by the impounding of surface drainage within the outcrop of the Lower Coal-measures and Millstone Grits.

2.—Southern District—Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher,
Mr. George Barrow,
Mr. J. B. Hill,
Mr. D. A. MacAlister,
} Geologists.

Field-work was carried on in 1905 in areas in Cornwall adjoining those surveyed in 1904; Mr. Ussher completed the country near St. Austell (347); Mr. Reid finished the Mevagissey map (353); Mr. Hill continued his work southward in the Helford district (359) to the boundary of the Lizard serpentine. Messrs. Hill and Reid, in the light of new discoveries near Gorran and Manaccan, re-examined the area between Tregony and St. Agnes (346, 352). The main interest of this work lies in the light it throws on the obscure region of West Cornwall. Mr. Reid.

In areas further north Mr. MacAlister continued the mapping near Roche (347); Mr. Barrow examined the country near [redacted]

Bodmin and Bodmin Moors (336 and 347); and Mr. Reid worked south and west of Wadebridge (335, 336, 347).

Mr. Reid and Mr. Hill. In the regions in which Lower Palæozoic rocks occur, Mr. Hill in the Helford district found that the Upper Palæozoic conglomerate is locally to a large extent composed of boulders of Portscatho Sandstone; thus showing that the Portscatho series, and also the associated Falmouth and Mylor series, are Lower Palæozoic, not Upper Palæozoic. This led to a re-examination of the Veryan area by Mr. Woodward, Mr. Reid, and Mr. Hill. The result of this was to show the presence of two distinct sandy series, by no means easy to separate where they come together with no conspicuous conglomerate between. The upper series (basal Devonian) consists of sandy silts, grits (the Grampound Grit, etc.), and conglomerates; but the conglomerates rapidly die away or become finer-grained north-westward, away from the old shore-line. These Devonian rocks are comparatively soft and are slightly calcareous; they are greatly disturbed and infolded parallel to the old shore line, both in the Gorran area and around Manaccan; but from Creed westward their base follows the normal east and west strike usually found in the Devonian rocks.

Mr. Reid. Many years ago Mr. C. W. Peach found in the Gorran area a certain number of fossils considered to prove the Caradoc age of the quartzites; on their authority an ill-defined area has long been coloured Lower Silurian on the maps. The brachiopods found by the Survey and mentioned in the last Summary were clearly of Lower Palæozoic type; but during 1905 Mrs. Reid found on the beach masses of a peculiar fine-grained iron-grey rock full of detached segments of trilobites. The rock proves to be a thin band, probably only six inches thick, not yet found in place, but met with adhering to a fallen block of fossiliferous quartzite containing numerous specimens of *Orthis calligramma*. This thin band yields a trilobite-fauna of seven or eight species. It also contains several species of *Orthis*, but scarcely a trace of other fossils. Its exact age will be discussed in the Memoir on the district.

The fossiliferous quartzites in the Gorran area come in close proximity to the basal Devonian rocks, and seem to be the highest Lower Palæozoic strata preserved in place. In the midst of them, however, as mentioned in the last Summary, occur one or two belts of disturbed rock or crush-planes, along which appear abundant masses of fossiliferous limestone of Ludlow and Wenlock age. Such masses occur in close association with the Gorran quartzite all the way from Perhaver Beach near Gorran Haven, through Porthluney and Kiberick Cove to the region south of the Helford River. This association, though not conclusive, for Lizard rocks also occur along this plane of movement, suggests that not far from the Ordovician strata occurs to the south a belt of Upper Silurian calcareous rocks.

Mr. Reid and Mr. Hill. Unfortunately we are still unable to find characteristic zone fossils in any other part of the Lower Palæozoic series, and the disturbance in the Gorran area is too involved for the satisfactory

proof of any definite sequence. But by piecing together the various fragments we get indications of a succession approximately as given below :— Mr. Reid and Mr. Hill.

	Ludlow limestone	only known as large masses in the disturbed belt.
	Wenlock limestone and calcareous slate	
Gorran Haven and Veryan Beds.	Black slates, quartzite, and pillow lavas, etc.	
	Sandy strata and moderately coarse grit.	
	Manganiferous slates, limestones and radiolarian chert.	
	Portscatho slates and grits (calcareous above).	
	Falmouth series.	
	Mylor slates.	
	Dodman series.	

As regards the Dodman series, it is very difficult to say where it should come in. The area in which it occurs is entirely isolated by a fault, and the rocks seem to be quite unlike anything else in Cornwall. They are more altered and are more like true phyllites than the associated strata, and they may be altered rocks belonging to the Mylor series, occurring in a region of great movement. Mr. Reid.

It is doubtful whether all the Lower Palæozoic strata should be called Lower Silurian, or whether some of them may not be Cambrian or older. The process of differentiation in the "killas" of Cornwall has been a very gradual one, and this large mass of slaty rocks is slowly being divided up among different formations. This division was evidently looked forward to by De la Beche, who discerned that strata of various ages might have been grouped together. Even in his lifetime the Gorran rocks were proved to be Lower Silurian, and recognised as much older than the fossiliferous Devonian strata described by Sedgwick and Murchison. But though these two areas were picked out and coloured respectively on the maps as Lower Silurian and Devonian, yet their boundaries were so obscure that no lines were engraved. The unfossiliferous area in West Cornwall was left in the general spread of Killas, though in the later issues of the map the Devonian sign and colour was used, for the only recognised fossiliferous rocks out of the Gorran area were undoubtedly Devonian. Until the unconformity and conglomerate were traced it was impossible to make any distinction.

The basal Devonian strata still yield many questions for discussion—questions which it seems impossible definitely to settle until a much larger series of fossils has been found. We cannot yet prove whether the littoral deposits of Gorran, Manaccan, and Grampound represent the base of the whole Devonian system, or represent merely an overlapping local base, varying in its geological horizon from place to place.* It seems, however, probable that no part of these basal rocks can represent strata higher than the Staddon Grit, nor as low as the Lower Old Red (Dartmouth Slates) for they are of marine origin.

In the Gorran and Veryan district Mr. Reid traced out the relations of the coarse basal conglomerate to the Lower Palæozoic rocks. He found that along an east-north-east and west-south

* Summary of Progress for 1904 (*Mem. Geol. Surv.*), p. 23.

Mr. Reid and Mr. Hill. west line the Devonian conglomerate is in contact with, and is apparently largely formed from material derived from the Ordovician and associated volcanic rocks. It contains also a considerable number of pebbles belonging to an older gneissose and schistose series, mixed with igneous rocks of unknown origin. These pebbles increase in number near Portloe.

Mr. Hill. In the Lizard district Mr. Hill finds also that the conglomerate, as already mentioned, is largely composed of boulders of Portscatho Grit, mixed with schistose rocks. It contains indeterminable corals and other marine fossils.

Messrs. Reid and Hill. North of Veryan the Devonian base sweeps round a wide anticline occupied by Lower Palæozoic rock, and passing north-east of St. Michael Caerhays trends north-westward towards Creed; then following the normal east and west strike of the Devonian strata it passes north of Truro and Scorrier to Porth Towan. As the strata are traced away from the old shore-line, and away from the area where Ordovician quartzites occur, they rapidly take on the character of grits, which merge into fine-grained silty deposits, often only separable from the older rocks through their much greater softness, for in many places no conglomeratic base can be found. The coarse grits of Grampound, Ladock, and Chapel Point seem to be merely local and impersistent sandbanks, which cannot be traced for any great distance; at Ladock they have yielded a single badly preserved fossil (now in the Truro Museum) which Dr. Ivor Thomas thinks is probably a new species of *Orthis*. A noticeable characteristic of the sandy and silty strata is the appearance in them of thin bands of cherty or silicified grit—like those used for monoliths and gate posts on the downs north of St. Columb Major, though not so thick. In fact, the resemblance between these two sandy areas is very striking.

Messrs. Reid, Ussher and Barrow. It will be convenient, next to turn to the area north of the Watergate Bay anticline. The examination of this area is still incomplete; but apparently the calcareous rocks of Beacon Cove and Mawgan reappear at Rosenannon, as hornstones of a peculiar type, which are traceable, mixed with greenstones, eastward through Withiel to Lanivet, then sweep south-eastward towards Lostwithiel, turning eastward again on the north side of the Lansallos anticline of Dartmouth slates. This shows that the two anticlines are continuous, the axis merely sinking on either side as it approaches the granite area, and swerving a little from its east and west course near Lostwithiel. Thus the Dartmouth slates are lost; but the next division, the calcareous Meadfoot slates of Beacon Cove, Mawgan and Fowey, is continuous, the main calcareous mass occurring some little distance above the purple and green slates. As to the continuity on the north side of the axis there seems no doubt; but on the south of the anticline there is still some difference of opinion.

Mr. Reid. From Newquay to St. Columb Porth Mr. Reid has traced similar calcareous rocks eastward, with the normal strike of the Devonian rocks. As they approach the granite they here also

pass into hornstones of a peculiar type, first seen at Fraddon. These hornstones have been traced by Mr. MacAlister from Goss Moor to Roche, where they seem to abut against the granite without any deflection. If east of this point they follow the same curve as the northern outcrop, and as the anticlinal axis, they should reappear towards Par and then sweep eastward again towards Fowey, as they appear to do. These strata cannot be recognised in the rocks of Black Head, which seem more closely to resemble the black slates of Holywell Bay, containing, like them, thin calcareous seams and scattered stems and ossicles of crinoids. South of Pentuan no rocks of this character are to be found, and careful search is needed to find any band that will effervesce with acid. Mr. Ussher's view of the relations of the rocks in this area is given below.

Mr. Mac-Alister.

Mr. Reid.

The completion of the mapping of the Devonian area on the east of the St. Austell granite mass, between Par and Lostwithiel, has shown the marked influence that mass has exercised in deflecting the general strikes from their normal east and west, to north and south, directions. The area in which these deflected north and south strikes prevail has a maximum breadth of 4 miles, from the vicinity of Lerryn to the granite margin due west of it; its length is conterminous with the irregular north and south trend of the eastern boundary of the granite.

Mr. Ussher

The zone of contact alteration varies from $\frac{3}{4}$ to a mile in breadth; arguing a comparatively low gradient in the easterly subterranean slope of the granite. There are probably two north and south faults, but of these only one can be detected with certainty—a northerly prolongation of a north westerly fault seen in the coast at Coombe Hawne, near Fowey, which cuts off the westward extension of the Dartmouth slates at Castle Dore. A W.S.W. fault uniting with this dislocation at Trenythen brings up a small patch of Dartmouth slates on the north near Polmear (Par sands). The probability of the termination of this patch on the west by a fault running parallel to the Castle Dore dislocation must be admitted, although no evidence of it was obtained on the ground. As the Castle Dore fault is traced northward its throw diminishes so that Dartmouth slates are found on both sides of it, and it cannot be traced further. The Dartmouth slates, unless the existence of a north and south fault to the west be conceded, must, therefore, form an anticline which terminates in the Fowey river valley at about three-quarters of a mile south of Lostwithiel, and throws off slates of the Meadfoot group, in which the fossiliferous strata of the Looe types are represented, on the west, and slates of the same group in which fossils are extremely scarce, and in which these fossiliferous horizons have not been detected, on the east.

On either side the boundaries of the Dartmouth Slates are extremely indefinite. The grit shales associated with them are indistinguishable from grit shales in the Meadfoot group, and the distinctive variegation which characterises the series as a whole gives place to pale grey or lavender grey, buff and other

r. Ussher. non-distinctive hues in places where their boundary is not a fault, so that no definite line of demarcation can be recognised The dark slates and grit shales to the west of the Dartmouth Slates are for the most part within the zone of contact alteration and exhibit the usual spotted type of alteration. The presence of fine calcareo-siliceous sediments in them is denoted by hornstones of the Peak Hill type which cannot be traced in a continuous series. A good exposure of these banded porcellainized rocks is to been seen near Treesmill (in the south-west corner of 6-inch map 42 S.E.) on or just outside the normal limit of contact alteration. From Treesmill to Par station the occurrence of hornstones in the slates may be inferred from occasional surface stones. In the slates in the cliffs from Par to the Blackhead* the unaltered hornstone horizons are probably represented amongst the subordinate partially calcareous beds and occurrences of small patches, or disturbed bands, of igneous origin. The absence of hornstones in the zone of contact alteration, south of the St. Austell granite would thus be accounted for by a more southerly outcrop.

The north and south strike on the east of the St. Austell granite renders it highly probable that the hornstones evidenced in places north of Treesmill, and conspicuous near Lostwithiel and south of Lanhydrock† belong to the same series of more or less calcareous rocks locally associated with igneous (volcanic ?) materials. On the north of the granite similar types have been recognised along the normal east and west strike toward St. Columb Major.

Specimens from the harder beds which overlie the Grampound Grit near Pentuan, and are present more or less continuously in the lower part of the slate cliffs, from thence to Par and on the opposite coast at Polkerris were submitted to Dr. Pollard to test for lime and phosphate.

His report is as follows—"I have examined the following specimens for the constituents you require to know about—1 Polkerris; 2 Polgwyn Beach; 3, 4, and 5, Cove between Black Head and Drennick; 6 Near Gammas Point, Pentuan; 7 Polrudden Cove, Pentuan. All are impure carbonate of Iron, Lime and Magnesia with some Phosphate and organic matter In No. 2 the portion soluble in hot dilute acid consists mainly of Iron and some Magnesia, with a little Phosphate and very little Lime."

The completion of the area between Pentuan and that previously surveyed by Mr. Scrivenor at Ladock demonstrates the intimate relation of the Grampound Grit series, (suggested as the base of the Devonian in 1891‡) to the slates with quartz eyes and films on the north. The boundary, if such it can be called, is only recognisable by a more sandy character, manifested in different ways. The dark slates with quartz eyes and films give place southward to more even slates with occasional hard fine sandy

* See Summary of Progress for 1903, p. 21.
† See Summary of Progress for 1902, p. 166.
‡ *Trans. Roy. Geol. Soc. Cornwall*, 1891, with Map.

beds (resembling the Portscatho type) and in these the grey and buff weathered greywacke or gritty masses characterising the Grampound type occur in a somewhat irregular and impersistent manner. Where this type is developed in the upper part of the even slate series as at Pentuan, and between Grampound Road and Ladock, a boundary can be fixed with precision, but in the intervening district this is seldom possible. Fine-grained rock of the Grampound type has been encountered in the shafts of the Commerce Mine, now being worked. In lithological character the Grampound types afford a strong resemblance to the Wearde-Efford greywacke in the upper Devonian districts of Plymouth and Saltash; but the development of apparently unfossiliferous argillo-arenaceous strata and of intercalations of grit in the lower parts of the Meadfoot group in the area west of Looe makes the assignment of the Grampound series to the lower part of that group extremely probable if not absolutely certain. Mr. Ussher

Staddon Grit.

Little need be said about this division, which forms the range of hills between St. Breock Downs and Bodmin. The first impression of this area, given by its height, and its numerous monoliths and scattered blocks, is that it is formed of a mass of sandstone and very hard grit. It is found, however, that wherever the streams have cut channels deep enough to show the rock—which they seldom do—the strata exposed are fairly fine-grained, soft, silty sands or slates, in which occur, at rare intervals, thin bands of hard cherty grit, apparently with a maximum thickness of 4 or 5 feet in any one band. Mr. Reid.

The dominant constituent of the more northerly and higher beds of the Lower Devonian (the Staddon Grit) can be best studied in the long quarry opened on the north side of the railway cutting about a mile to the east of Bodmin. By far the greater part of the rock here exposed consists of finely bedded, very fine sandy silt, in which the difference in composition of the alternating laminæ is not at all sharply marked; and this fine lamination can be seen only in fairly fresh specimens when closely examined. The rock weathers to a somewhat mottled pink and grey colour and is so soft that it can be cut or hacked with a strong knife. Though a very large face is here exposed only two small bands of distinct grit are present, one of which is a hard, grey, fine grit about 6 inches thick, while the other is about 2 feet thick, quite soft and markedly felspathic. In this rock, the dynamic forces by which the region has been affected, have largely crushed the felspar grains to a micaceous material which makes it so incoherent that it is impossible to obtain a good specimen. Most of the felspathic grit bands in this series show the same character, and in most cases it is only the chloritic greywacke type of bands that are hard and durable in the Bodmin area. The fine lamination of the silt at this cutting enables the true dip to be observed, which is undulatory giving an average dip to the north-east of about 50 degrees. Mr. Barrow.

Mr. Barrow. Associated with the more northerly portion of this group of rocks are some rather thick bands of grey slaty material closely resembling that of the overlying Middle Devonian, so that there is no sharply defined lithological break between the two groups, but rather a passage, and this causes some difficulty in fixing the boundary between the two. The slaty beds associated with the Staddon Grit have, however, been proved by quarrying to be rather harder and more durable than the slates of the higher horizon. A specially good exposure of this harder slate occurs in the large quarry close to the Bodmin Asylum. Crinoid ossicles are fairly common in the spoil heap of this and other quarries in the same bands, while a few specimens of other fossils have been met with; the latter seem too distorted to be of any zonal value.

The typical sandy silt already described often passes into rock more markedly siliceous and slightly coarser in texture; but true grit bands are not common in the Staddon Grit group of the Bodmin area; and when they do occur they are rarely much more than 2 feet thick. Good examples have been cut open in the section of the Great Western Railway between Bodmin and Boskarn and they are more numerous than usual at the latter locality. Here a special feature of the chloritic or greywacke types can be well studied; they are cut up into thin lenticles (thrust-plane structure) by planes of movement, exactly as in the Southern Highlands or in any other area affected by dynamic movements of a regional type. The thickest band of greywacke so far met with occurs at Kirland, about a mile due south of the Bodmin Beacon.

South of this bed of greywacke the silt, in which the laminæ do not contrast strongly in composition, is succeeded by a finely banded material in which this contrast is most pronounced. These rocks are composed of thin layers of pale yellow and markedly siliceous material, alternating with films originally of dark grey mud; and this type forms the dominant constituent of the area further south for a great distance. Associated with it are a few thin bands of the silt and the harder grey slate, while, more rarely, a bed of grit may be met with; but these rarely attain a thickness of 2 feet and are usually thinner. Well within the group, however, one or more calcareous bands have been met with which must at times have a considerably greater thickness, though owing to the folding this is difficult to estimate. These calcareous bands will be referred to further on; for the present it is sufficient to note that they show that the rocks associated with them must belong to the Meadfoot Series; but there is no evidence in this area by which to fix the boundary between this series and the overlying Staddon Grit.

MIDDLE AND UPPER DEVONIAN.

Work on these divisions has lain principally in the district between St. Breock Down and Bodmin Moor.

As regards the area between Bodmin and Bodmin Moor, a brief description of the great mass of highly argillaceous grey

slaty material of Middle Devonian age, was given on page 26 of the Summary for 1904, and no marked differences have been met with. But as the neighbourhood of St. Neot was approached, an altered calcareous band was found, which is interesting both from its mineralogical composition, and the fact that it suggests a slight change in conditions of deposition. This calcareous material was first met with as small isolated fragments on the Moor west of Mount. These blocks are dark grey in colour and of flinty aspect, suggesting the quickly-cooled margin of a dyke. Further east they become more numerous and larger; and moreover are well banded, showing that they are of sedimentary origin. The parent rock is first seen at Pantersbridge, where it is interbanded with the dark, almost black, slate, once extensively worked at St. Neot. As the village is approached, the blocks are still more numerous and larger, and can be recognised at once by a curious ribbing developed on their weathered surfaces. This portion of the outcrop lies on the outer margin of the aureole of metamorphism produced by the Bodmin Moor granite, and the calcareous rock here contains a great number of small grains of epidote and zoisite. The band will probably prove of considerable value in tracing the zones of the Devonian Rocks further east. Mr. Barrow

Granite.

A considerable portion of the Bodmin Moor granite has been mapped, and a small part of the northern margin of the St. Austell mass. The Bodmin Moor granite retains for the most part its normal composition, but the mapping has shown that there is a large mass of the rock singularly free from greisen-lines, or any form of small intrusions, and remarkably uniform in composition. The absence of greisen-lines seems to be accompanied by the entire absence of tin veins, for not a single trial even has been met with in this area. Still more significant is the fact that under the long belt of alluvium flanking the De Lank River, very little stream-tin has been found, although the ground is of the form that elsewhere has proved singularly rich in other parts of the Bodmin Moor granite. In two cases the alluvium of the De Lank and its affluents approaches the margin of the massive granite area; and here the tin ore was found in slightly greater quantity.

On both flanks of the area greisen lines and schorl-rock are more or less abundant. On the north-west side they accompany a number of fine granite veins, which close to St. Breward seem to coalesce and form a more or less continuous mass of finer granite. To the south-east, not only is schorl-rock abundant, but patches of china-clay also occur, and in this district stream-tin was found in great quantity in all localities suitable for its aggregation. Tin-veins are still rare, though numerous small trials show that minor ones, too small to pay for working, occur here and there. It is not till Treveddo, five miles south-east of De Lank, is reached that the first payable vein has been found.

Mr. Barrow. The northern end of the St. Austell granite differs from the mass just described, not only in composition, but also to a more marked extent in the phenomena observed on its margins. In the typical rock the orthoclase crystals are persistently much larger, and in addition there is distinctly less white mica than in the Bodmin Moor mass. But it is the development of schorl rock veins outside the granite that seems to characterise this intrusion. This material occurs as threads or veins in the Killas in great quantity, and at distances varying from a few hundred yards to a mile or more. Moreover, in the laminated rocks of the Meadfoot series, the development of schorl extends outwards from the little veins into and along the shale films, rendering them almost black. The originally strong contrast between the laminæ of these rocks is thus intensified, for the siliceous films are not attacked to nearly the same extent, and rarely lose their pale colour. This extensive development of schorl-rock is accompanied by the occurrence of crystals of tin-ore along small threads, at equally great distances from the granite margin, a phenomenon not yet met with in the case of the other intrusion As the Killas rotted, the tin-ore was set free and washed down into the nearest hollow where it could lodge; so that in following the course of small streams near the granite area, old workings have been met with in the most unexpected places.

While much of the north end of the St. Austell granite is riddled with greisen-lines, a considerable portion of the intrusion is comparatively free from these planes of weakness, so that again an area of more solid weathering rock occurs, and in this a few tors have been developed.

It may be noted that numerous large blocks of a rock, closely approaching Luxulianite in composition, have been met with at many localities, and the parent rock has been found *in situ* in an adit to the old mine on the crest of the hill where the granite is nearest to Bodmin.

The very impure Meadfoot limestones already referred to (p. 31) have a considerable outcrop within the zone of pneumatolytic action. Owing to their extreme hardness, they are extensively quarried for road metal, and the action of the gases which penetrated the innumerable cracks in the brittle material can be specially well studied. It has been found that the small cracks penetrating the typical fine hard yellow (epidotic) rock, are most commonly filled with small crystals of hornblende. When the calcareous rock is finely banded this hornblende, here actinolite, extends from the vein along the darker bands in exactly the same manner as the schorl does in the case of the sandy shales already described. When the banding is absent the hornblende is more closely confined to the actual veins or ramifying cracks, and if it penetrates the body of the rock does so irregularly. When the cracks are broader there is a much greater variety of minerals present, and this is especially the case when the adjacent limestone is darker coloured, and of a more complex composition originally.

In one case a crack nearly 6 inches broad has been met with in which the infilling material is composed essentially of axinite and a pale pyroxene; the whole band being far more coarsely crystalline than any rock altered simply by the heat introduced by the granitic mass; indeed this curious axinite-rock is well outside the granite aureole of metamorphism. As the result of a preliminary examination of the minerals thus developed Mr. Thomas has identified axinite, pale pyroxene, actinolite, blue-green hornblende, pink garnet, orthite and micaceous haematite. Axinite seems to be the characteristic mineral of all but the smaller cracks, and is abundantly developed in this area. The crystals are often more or less idiomorphic, and agree in form with those from Dauphinée; they rarely, however, possess the same deep tint, but vary from yellowish to pale lavender. As there is no difficulty in obtaining a considerable quantity of material a full investigation will be made of these interesting minerals. Mr. Barrow.

The northern outcrop of these axinite-bearing calcareous hornstones has been traced from Rosenannon on the north-west, through Withiel and Lanivet, to the country south of Bodmin. The southern outcrop is well seen near Roche. Mr. Reid.

Elvans.

Elvans are fairly numerous on the margin of the Bodmin Moor Granite, especially in the Warleggon district, where they are not only broader than usual, but at times have such a low hade as almost to simulate sills in their mode of occurrence. So far none of these dykes met with are protrusions from the margins of the granite, but rather intrusions into it and of slightly more recent date. In one case, on Cardinham Moor, an elvan has been traced as an intrusion in the granite, more or less continuously for nearly two miles, and there can be little doubt that it also cuts the killas on the margin of the granite. Mr. Barrow.

One specially interesting dyke has been met with a little north of Helland, where it occurs along the bed of a small stream. In the central part the rock is essentially a fine granite, and it weathers to a great number of large and intensely hard blocks. Its trend is roughly N.W., or parallel to the margin of the Bodmin Moor granite, from which it is nearly 3 miles distant.

Basic Igneous Rocks.

Basic igneous rocks have been met with on at least two horizons, one high up in the Middle Devonian, the other associated with the calcareous rocks of the Meadfoot series already referred to. The band or bands at the higher horizon have been traced for some miles at the south-west margin of Bodmin Moor, and in one place the original mode of piecing together of the minerals can be clearly recognised showing the original rock was a coarse ophitic dolerite. The bands at the lower horizon south of Bodmin, are persistently fine-grained

Mr. Barrow. and apparently much altered, so that their original structure is not yet known. That the rock first referred to is a sill is clear from the induration of the beds on both sides. At the suggestion of the Director a considerable number of specimens from the margins of this intrusion have been collected, not only to study this original induration, but because it is clear that these previously indurated rocks present special phases of metamorphism when they enter the granite aureole of alteration.

ECONOMIC GEOLOGY.

Mr. Ussher. *China Stone.*—The china stone district of the St. Austell granite extends north from the granite margin at Tregargus Mill, near St. Stephen. In this district the granite is white or pale buff, of a rather coarse or medium grain, but without porphyritic felspars, and exhibits pale greenish-yellow particles from the alteration of muscovite. Its variable hardness is due to different stages in the kaolinization of the felspar constituents, permitting of its employment as a local building stone in some cases, whilst in others it forms an evenly jointed easily disintegrable rock. Fluor is often found on joints or disseminated in the rock. The best stone is that which contains least mica, or "shell" as it is locally termed. The stone is exported in the raw state, or ground to a fine white powder, by revolving stone-runners, as at Tregargus Mill. The captain of the Tregargus works estimates the difference in price of the raw stone and ground as between 12s. to 14s. per ton for the former and from 25s. to 30s. for the latter. At Bloomdale works china stone has been quarried to a depth of 100 feet or more. The breadth of the district worked for china stone between Trethosa clay pit on the west and Gonnabarn and Carloggas clay pits on the east is about $\frac{3}{4}$ of a mile. The china stone industry has not developed sufficiently to make prospecting for workable stone in the waste areas between the china clay workings necessary or profitable. In most of the china clay pits solid, or partly decomposed granite occurs in, or bounds, the kaolinized material, but is quite unsuitable for the manufacture of fine porcelain for which the china stone is used. "Stent" or quartz-schorl veinstones are very unequally distributed in the kaolinized granite, and in many of the productive pits are almost or altogether absent. Where veinstones abound the clay is used for pottery and termed "blue potting clay."

The topography of the 6-inch Survey has been modified and in places entirely altered through the growth of the China Clay industry. Great deep pits often occupy the places where settling pits, tanks, dries, and engine-houses are shown on the 6-inch map.

Mr. Mac-Alister. *China Clay.*—The distribution of the china clay is not limited to any one part of the St. Austell granite, but is, here and there, widespread throughout the mass, with the exception of the north-east portion where the rock, although not always free from secondary alterations, is fresh and sound. The numerous clay

pits, some of which are of enormous size, afford excellent opportunities for viewing the nature and general shape of the workable masses of china clay. The well known fact of its association with lines of greisen action has been brought out forcibly during the recent survey of the district, and the facts observed point to conclusions of importance in the location of possible new bodies of china clay in areas at present unexplored. Mr. MacAlister.

Large masses of this material which have not been worked upon, frequently, as pointed out by Mr. Collins* and others, betray their presence by the general appearance of the surface of the ground about them; the position of any particular mass being indicated by a slight, scarcely noticeable, depression or else a flat place (called a "slad") in which the sinking of a few pits would easily prove the exact nature of the material. But the determination of new sites near places in which china clay already worked is facilitated by a study of the phenomena revealed in the clay pits already opened.

In the area comprised in the six-inch Sheets 41, N.E., S.E and S.W., there is a remarkable system of fissuring (or jointing) having a bearing of about N. 45° E. The bearing of the fissures varies slightly in different localities and frequently, as seen in both the clay pits and the mines, another system crosses it at a small angle. The fissures as a rule are very narrow and are not accompanied by faulting or brecciation. They often occur in groups in which the fissures are parallel and quite close together, each holding its own course with remarkable precision and independence. The fissures may contain quartz, coarse schorl ("smuts"), peach (fine grained schorl-rock), cassiterite and wolfram, but many of them are empty cracks.

On each side of the fissures there are, very often, hard bands of greisen or schorl-bearing rock. The width of such bands depend to some extent on the width of the fissures they enclose, but where the fissures are very close together the whole of the county rock may be altered to greisen or schorl-rock. Beyond the veins and the hard bands accompanying them the granite is changed to china clay rock from which the china clay is extracted by means of a stream of water; and as china clay expands when moistened a particularly powerful stream is not required for the disintegration of the rock.

Fine examples of greisen veins are to be seen exposed in the clay works of North Goonbarrow, Martin's clay works and other places; while instances of very wide masses of schorl-rock derived from granite are associated with the china clay that occurs at Singlerose,† and the Lantern works.

Goonbarrow, Caudledown and South Caudledown furnish excellent examples of the association of the china clay with several series of very narrow, more or less parallel veins situated close together and having but little of the hard altered rock so frequently accompanying veins of this type.

* "Hensbarrow Granite District," 1878, p. 7.

† Referred to by Dr. Teall, F.R.S., British Petrography, p. 315.

Mr. Mac Alister. It is evident, therefore, from the china clay being an altered granite traversed by a number of parallel veins, that bodies of china clay ought to be met with here and there along zones in the granite in which the veins occur; and actual observations have revealed the fact that many of the clay pits now at work have a general linear distribution in the direction of strike of the veins, sometimes extending sporadically for miles. In fact the pits themselves are often oval or oblong in shape (*e.g.* Rose Mellyn; Old Beam; Central Treviscoe, etc.). Frequently the alteration of the country rock is so far reaching, through extensive fissuring, that many of the works occur in groups with no obvious linear arrangement. The linear distribution of the clay pits is, however, illustrated over and over again, but as the veins are not always accompanied by extensive kaolinisation, or else they diminish in number, the china clay is sometimes "cut out" by harder rock which, when it comes between two clay works is called a "bar of rock." The term "bar" is appropriate for it is sometimes a wall-like barrier of hard rock separating one clay work from another and striking in the same direction as the fissures of the country. A "bar" of rock separates Goonbarrow from North Goonbarrow, and "bars" separate the Old Beam clay works from Wheal Hope on the one side and from East Goonbarrow on the other.

These harder masses do not always occur with such regularity and it is not uncommon to find hard rock in the middle of a clay pit, or here and there the clay cut out in depth by it, as at one of the pits at Little John's china-clay works, south of Coldvreath. Except for this more or less uncertain occurrence of the clay there appears to be no limit to the depth to which it may go and some of the deep pits show no signs that the amount of clay is diminished with depth. At Caudledown, for example, there is an immense excavation nearly 50 fathoms in depth still being actively worked.

3. South Wales District—Carmarthenshire and Pembrokeshire.

Mr. Aubrey Strahan, M.A., F.R.S.. District Geologist.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A., B.Sc.
Mr. O. T. Jones, M.A., B.Sc.
} Geologists.

Mr. Strahan. The field-work of 1905 lay in the Ordovician tract around St. Clears, Whitland, and Lampeter Velfrey, in the Old Red Sandstone and north crop of the coalfield between Templeton and the Eastern Cleddau, in the coalfield between Amroth and Jeffreston, and in the tract between Tenby and Pembroke on the south side of the coalfield.

Ordovician.

Messrs. Cantrill and Thomas. The work in the northern part of the district has lain in the neighbourhood of St. Clears, Whitland, and Lampeter Velfrey, on

the Ordovician, Silurian and Old Red Sandstone rocks. The following table shows in descending order the sequence of the rocks below the Old Red Sandstone :— Messrs. Cantrill and Thomas.

SILURIAN (part of)	Llandovery.	*Lower Llandovery.*—Grey quartzitic sandstones, and shales and mudstones, with a conglomerate at the base ; fossils rare.
ORDOVICIAN	Bala	*Slade and Redhill Beds.*—Blue-grey mudstones with bands of decalcified sandy mudstones and some micaceous sandstones ; corals, crinoids and brachiopods locally abundant. *Sholeshook and Robeston Wathen Limestones.*—Dark thin-bedded limestones, with *Cybele verrucosa*, *Encrinurus sexcostatus*, *Illœnus Bowmanni*, *Halysites catenularia*, etc.
		Dicranograptus Shales.—Black and brown-weathering shales, and shaly limestone (Mydrim Limestone), with *Dicranograptus*, *Diplograptus*, *Climacograptus* and *Leptograptus*.
	Llandilo	*Didymograptus Murchisoni Beds.*—Ashy flags, ashes, and impure limestones, with *Ogygia Buchi*, *Asaphus tyrannus*, and other Llandilo forms above striped ashy flags with abundant *Didymograptus Murchisoni* passing upwards and downwards locally into ashes.
	Arenig	*Didymograptus bifidus Beds.*—Blue-black soft shales, with *D. bifidus* and other forms characteristic of Dr. Hicks's Lower Llanvirn fauna.
		Tetragraptus Beds.—Blue-black iridescent-weathering shales and blue mudstones with *Didymograptus hirundo*, *D. extensus*, *D. nitidus*, *Tetragraptus*, etc. Fossiliferous and conglomeratic grits towards the base. Shales with *Ogygia marginata* and grits with abundant *Orthis*.

Arenig.

Tetragraptus Beds.—The district around Henllan Amgoed is one of a complicated and overthrust anticlinal structure, the axis of the anticline lying a little to the south of Henllan church and stretching in an east and west direction. The centres of the folds which constitute the compound anticline are occupied by sandstones and grits which are characterised by an abundance of a small *Orthis*. These grits are succeeded by gritty shales, with irregular surfaces, which yield *Ogygia marginata* and other forms identical with those of the Carmarthen district.* It Mr Thomas.

* Summary of Progress for 1904, p. 33 (*Mem. Geol. Surv.*)

Mr. Thomas. is certain that these shales at and near Henllan occur below those with a typical *Tetragraptus* fauna; but until the surrounding area has been completely mapped it is thought advisable not to refer them to any very definite horizon. It is, however, probable that at Henllan we are dealing with a series of deposits of almost exactly similar character to those displayed in the Bolahaul and Cistanog district near Carmarthen, and at Llangynog, all these three areas being anticlinal in structure.

The "*Orthis* grits" occupy the summits of three hills, the largest mass lying to the east of Henllan church, and the two smaller masses, one to the south of the church and the other to the south of Blaen-wen-eirch Farm. To the south these beds apparently overlie the ordinary *Tetragraptus* shales, but, from the course of the boundary between the two sets of deposits it is almost certain that the junction is a thrust-plane which slopes very gently towards the north. Associated with the grits are some black mudstones and thick ash-beds, the former yielding abundant dendroid graptolites and *Dictyonema* in the valley to the west of Blaen-cediw.

The beds with *Ogygia marginata* surround the masses of "*Orthis* grit" on the northern, western, and eastern sides, and normally succeed them. They are well exposed near Henllan church, at Llwyn-derw Farm, and in lanes to the south and east, also in the dingle to the south of Henllan Mill. They may be seen to the east of Blaen-wen-eirch, and south-west of Gellidiogyn. The most fossiliferous exposures are those in the two lanes, near Llwyn-derw Farm, leading down into the valley of Felin-boeth.

Mr. Cantrill. The beds with a typical *Tetragraptus* fauna form the core of an anticline which ranges through Llangynin westwards towards Whitland Abbey and to the south of Henllan-Amgoed. The rocks consist of blue-black shales with occasional bands of grit and conglomerate, especially in their lower part. Conglomeratic grits are exposed in the neighbourhood of Whitland Abbey and Cwm-felin-boeth, but west of the latter place disappear under the shales of Talfan (Vicarage), which belong to a somewhat higher horizon of the group. The grits yield occasional specimens of *Orthis* and trilobites; the shales, which are exposed in the Fenni and Gronw Valleys near Llangynin and Whitland, and also near Llangan, west of Whitland, are very poor in fossils, but have yielded occasional trilobites and graptolites of tetragraptid and extensiform types, the latter being especially abundant near the top of the group.

Mr. Thomas. North of Pass-by, the Cwm-felin-boeth grits are succeeded by the fossiliferous shales of Pen-pare-uchaf, which are identical with those of Talfan, and yield a typical *Tetragraptus* fauna. These shales, with interbedded and occasionally fossiliferous grits, stretch northwards to the hills capped by the Orthis grits described above; westward they extend towards Llanfallteg, and may be well seen in several railway cuttings between Llanfallteg station and Login, the next station to the north. A northern belt passes to the north of Henllan-Amgoed and occupies a broad

tract of country between that place and the river Tâf; they are succeeded normally near the northern edge of the map by *D. bifidus* shales. On the south side of the main anticline they pass up into *D. bifidus* shales at Llanfallteg, the junction being exposed in a cutting to the immediate north of the railway station. Mr. Thomas.

At present it is impossible to correlate the beds to the south of Henllan-Amgoed with those on the north, the deposits on the two sides of the anticline appearing to be of different character; nor is it possible to assign a definite position to the main grit masses in the *Tetragraptus* series taken as a whole until a larger area has been considered. Messrs. Cantrill and Thomas.

Didymograptus bifidus Beds.—An outcrop of these shales lies on each side of the area of *Tetragraptus*-beds just described. This base has been drawn at a horizon at which graptolites of the *D. bifidus* type first appear, though the extensiform graptolites range upwards for some distance. Mr. Cantrill.

The northern belt runs through the village of Llangynin and passes out of the map towards Llanboidy. The southern belt extends westward from St. Clears along the valley of the Tâf through Whitland to Lampeter Velfrey. In both belts the ashes in the lower part of the group persist westwards as far as the mapping has proceeded.

Shales with bands of ashes and ashy shale form the core of a faulted anticline ranging nearly east and west to the south of Lampeter Velfrey. On the north limb they appear to be succeeded conformably by the Llandilo Limestone. On the south they are faulted for the greater part of their course against the same limestone, but in places against what are probably Upper Bala beds. Close underneath the limestone of the north limb a small type of *Didymograptus* occurs in some abundance in the road leading south from near the church at Lampeter Velfrey, and again by the roadside west of Llan Mill. The ashes are excellently exposed in a little dingle a quarter of a mile east of the latter place. Mr. Jones.

North of the river Tâf the shales occupy the country around Cefn-farchen, Rhyd-y-wrach, and Llanfallteg station; the boundary line between them and the *Tetragraptus*-beds to the north being one of considerable complexity. The beds, which are for the most part inverted, as has generally been the case on the southern flanks of the main anticlines, cross the river Tâf and strike east and west at Llanfallteg West. To the south of the river they occupy the neighbourhood of Bryn, where they are presumably inverted, and faulted on the southern side against Redhill Beds and *Dicranograptus* Shales. In the main road east of Castelldwyran they strike along the drift-covered ridge towards Clynderwen. Mr. Thomas.

Llandilo.

The Llandilo Series as developed in the Cynin and Fenni Valleys between St. Clears and Llanboidy on the north side of Mr. Cantrill.

[r. Cantrill. the anticline is about 150–200 feet thick, and presents the following subdivisions in descending order:—

Ash and ashy flags with *Asaphus* and *Ogygia*.
Striped flags and ash with *Didymograptus Murchisoni*.
Thin, soft, black shaly mudstones with *D. Murchisoni*, var. *geminus ?*
Ash, thin and impersistent.

The series is well exposed at Castell Gorfod in the Cynin Valley, and at Nant-yr-eglwys in the Fenni Valley. On the south side of the anticline it is faulted out, except at Clog-y-fran, where a faulted lenticle of Llandilo Limestone comes to the surface.

Farther west, at Trewern, two miles west of Whitland, the *Dicranograptus*-shales overlie the following beds in descending order:—

White and grey fossiliferous ash.
Blue-black rough shales and mudstones.
Flags and rottenstones weathering brown (*Trinucleus*, etc.)
Blue-black mudstones.

These rocks appear to overlie the *D. bifidus* Beds and to represent the *Asaphus* ash and striped flags with *D. Murchisoni* of the north crop.

From Trewern south-westwards towards Llanddewi Velfrey there are occasional exposures of flags, rottenstones and limestones, also lying between the *Dicranograptus* shales and the *D. bifidus* beds.

At Lampeter Velfrey, on the south side of Lampeter Vale, the Llandilo Series appears to revert to the type as developed in the classic district of Llandilo. At the top of the *D. bifidus* Beds certain black shales crowded with small forms of *Didymograptus* are succeeded by a group of limestones, rottenstones, and flags, with abundant fossils, including *Asaphus tyrannus* and other typical Llandilo Flag forms.

[r. Jones. The *Llandilo Limestone* bounds the complicated anticline south of Lampeter Velfrey. In places along the south limb it appears to be faulted out altogether, while in others it is faulted on the one side against *D. bifidus* beds, and on the other against Upper Bala, or Llandovery beds. The base is a sandy ashy-looking limestone weathering to a dark orange-red rottenstone crowded with brachiopods and trilobites, the lithological change to this type from the soft blue-black graptolitic shales underneath being very marked.

The main mass is a flaggy, sandy limestone in its lower part, but becomes more massive higher up. Towards the top it passes into calcareous flags and shales which are well-exposed about the village of Crinow. The more massive beds were once extensively quarried about Llan Mill.

Lower Bala.

[r. Cantrill. *Dicranograptus Shales.*—North of the anticline the Llandilo Beds are succeeded by brown-weathering, fissile, black shales with

Dicranograptus and *Diplograptus*. They are exposed west of Mydrim at Castell Gorfod, Pen-lan, and Nant-yr-eglwys. Upward they pass into black impure limestones (the Mydrim Limestone), which at Castell Gorfod have yielded *Leptograptus*. This limestone, however, appears to pass laterally into shales at Pen-lan, and has not been traced west of the Fenni Valley. Above the limestone follow black fissile shales with *Diplograptus*, *Climacograptus* and *Dicranograptus*. Mr. Cantril

South of the anticline, at Trewern, we have found no representative of the brown-weathering *Dicranograptus* shales, or of the Mydrim Limestone, the black shales appearing to follow at once on the Llandilo Limestone. These black strata are exposed along the north side of Lampeter Vale between Whitland and Llanddewi Velfrey.

On the southern side of the river Tâf the same black shales occupy a small area between the alluvium of the river and the Bala Limestone of Ty'n-Coed west of Hendre. To the west they are faulted on the south against Redhill Beds, but the fault, which runs through Bryn, soon cuts them out, leaving Redhill beds in contact with *D. bifidus* Shales. Mr. Thomas

Bala Limestone Series.

Robeston Wathen and Sholeshook Limestone.—These limestones are absent on the north of the anticline, the black *Dicranograptus*-shales being succeeded at once by the Redhill Beds. Mr. Cantril

On the south, between Trewern and Llanddewi Velfrey, the limestone is well developed. It is quarried near Fron, where it consists of blue-black, fine-grained limestone with shaly partings and has yielded several corals, including *Halysites catenularia*. The limestone agrees in character with that of Robeston Wathen rather than with that of Sholeshook.*

A strip of limestone 350 yards in length occurs in its proper position between the *Dicranograptus*-shales and Redhill Beds to the south of Ty'n-coed; it is well seen in quarries on either side of the small hollow south of the farm, where it consists of a dark crystalline limestone poor in fossils, and of the Robeston Wathen type. Mr. Thomas

Upper Bala.

Redhill and Slade Beds.—These blue-grey mudstones succeed the Bala limestone, or, in its absence, as on the north of the anticline, the *Dicranograptus*-shales; they pass northwards across the Cynin Valley west of Mydrim, and are there unfossiliferous. On the south they are well developed in the ridge which extends westward from Trewern towards Llanddewi Velfrey, where they have been deeply trenched with picturesque cwms and dingles. They contain thin bands rich in fossils, including many brachiopods, lamellibranchs and corals, amongst which *Favosites fibrosus* is particularly abundant. Mr. Cantril

* Marr & Roberts, *Quart. Journ. Geol. Soc.*, vol. xli. (1885), p. 476.

r. Jones. South and west of Llan Mill the Llandilo Limestone is faulted on the south against blue or olive-green shales and mudstones with thin gritty bands weathering reddish-brown; they usually contain brachiopods, and crinoid remains in some abundance. They appear to be succeeded everywhere by a grey quartzitic sandstone probably of Lower Llandovery age. They are, therefore, probably of Upper Bala age, but this cannot be definitely settled until the fossils have been determined. The best exposure is in the railway cutting east of Blackalder, near Narberth.

·. Thomas. These mudstones occupy the country around Hendre and stretch westwards to the south of Castelldwyran and Ffynnonbrodyr. They are of the usual type and are abundantly fossiliferous immediately above the Bala limestone of Ty n-coed.

SILURIAN.

·. Cantrill. *Lower Llandovery.*—The Slade Beds which form the upper parts of the eastern slopes of Pale Mountain, west of Llandowror, are succeeded by a well-marked band of conglomerate, consisting of pebbles chiefly of fine-grained white quartzite in a dark-grey quartzitic matrix. This is followed by fine-grained sandstones and blue mudstones which rarely yield fossils.

These rocks have been traced westwards from Pale Mountain past Pen-y-back quarries, south of Whitland, to Lampeter Velfrey. They are faulted against *D. bifidus* Beds on the north and faulted against or overlain uncomformably by the Old Red Sandstone on the south. They occur also in the form of an outlier at Wheelabout* one mile north-east of Llanddewi Velfrey. Here the group is introduced by pebbly grits and sandstones, above which follow black shales and mudstones, apparently, devoid of fossils.

·. Jones. The Lower Llandovery rocks form a narrow strip ranging approximately east and west from south of Lampeter Velfrey to near Narberth Castle. The dip is southerly, but north of Blackalder there is another outcrop dipping in a northerly direction, the two forming the limbs of an anticline pitching west. They consist of dark-grey quartzitic sandstones, sandy shales and mudstones, with apparently some conglomerates. The large boulders of coarse conglomerate with well-rounded pebbles, chiefly of a white quartzite, which occur south of Gelli-'r-enwyn farm, and are probably derived from a crop hard by, are of the type found at the base of the series on Pale Mountain. Wherever the junction of the series with the underlying beds is exposed, there is an absence of conglomerate, but there is always evidence of some movement along and near the junction which may have cut it out. The sandstone is exposed near Penlan farm, south of Llan Mill, and in the railway cutting near Blackalder. On the south crop it is succeeded by sandy shales, and probably by olive-green mudstones, indistinguishable lithologically from some beds in the

* Marr & Roberts, *op. cit.*, p. 485.

Upper Bala series. Underneath the base of the Old Red Sandstone near Forest Factory and Narbeth Bridge there are abundant fossils in some mudstones of this type, but these have not yet been determined. Mr. Jones.

OLD RED SANDSTONE.

The basal green beds have been traced westwards from near Llandowror past Cyffic towards Lampeter Velfrey. They consist of about 800 feet of green and greenish-grey marls and sandstones, with occasional conglomeratic cornstones, but near their base contain bands of conglomerate and breccia, made up chiefly of pieces of felsitic rocks, vein-quartz, and quartzite, as, for instance, at Ffynnon-cyll, south-east of Whitland. Mr. Cantri

These green beds pass upwards by alternation into red marls, which contain, at some 500 or 600 feet above their base; a thin band of yellow incoherent quartz-conglomerate about 10 or 15 feet thick. This band first appears near Cyffic church, and has been traced thence several miles westwards.

The red marls in their lower part contain occasional thin bands of brown and yellow coarse sandstone and grit, one band of which is sufficiently important to have been quarried on the moorlands about a mile south-west of Cyffic church. Above this succeed red marls which extend southwards towards Red Roses.

The base of the Old Red Sandstone runs in a westerly direction from about half a-mile south of Narberth to the left bank of the Eastern Cleddau, south-west of Blackpool Bridge. It is exposed in several places along its course, always resting on olive-green mudstones. A conglomerate invariably occurs, usually in two or three thin bands, alternating with buff orange-weathering sandy mudstones which simulate very closely the underlying beds in lithological character and colour. These are, however, easily distinguished in most cases by being richly fossiliferous, but as fossils have never been found quite up to the conglomerate, there is always some uncertainty in regard to the age of a small thickness of the buff beds immediately underlying it. Mr. Jones.

The green marls and sandstones reaching a thickness of about 500 feet, mentioned in previous Summaries as forming the lowest subdivision of the Old Red Sandstone for many miles, have gradually disappeared westwards, probably by lateral passage into red beds of similar lithological character. The change began to be apparent to the South of Lampeter Velfrey, where red marls come in near the top of the green series, with about 400 feet of green marls and sandstones below them The change takes place rapidly towards the west, and in a distance of two miles the green marls have thinned to less than 150 feet, while a clear section on the bank of the Eastern Cleddau, about four and a half miles west of the last point shows only 2½ feet of green sandstones between the conglomerate and the lowest red band. In none of the cases hitherto noticed, however, does the red colour extend down to the conglomerate,

. Jones. but another section, less than a mile still further west, shows 2½ feet of red marls *below* the basal conglomerate. The gradual and progressive nature of the change makes it improbable that the disappearance of the basal green beds is due to strike-faulting. Further, a band of conglomerate which occurs in the overlying red marls is always found at a constant height above the base of the formation showing that such faulting, if it exists, cannot have the effect of cutting out any appreciable thickness of beds.

The main mass of the formation above the basal green beds, so far as they continue from the south of Narberth to what is probably its last appearance on the left bank of the Eastern Cleddau, is roughly divisible into two parts as remarked in the Summary of Progress for 1904, p. 40. The lower part consists of red sandstones, and marls with race, together with frequent thin bands of grey or green sandstones occasionally pebbly, and one well-marked band of conglomerate with rounded vein-quartz pebbles and a white felspathic matrix. This has been traced for many miles and always occupies the same position about 900–1,000 feet above the base of the formation. Near the outcrop it generally disintegrates to a coarse gravelly sand which has been frequently dug. It is interesting to note that the gravel used in building Narberth Castle was obtained from this source. An ancient trench over 200 yards long and 2 to 3 yards wide along the outcrop of the conglomerate ¼ mile south of Narberth Bridge bears witness to the large amount of material which must have been used. The total thickness of the red sandstones and marls seems to exceed 2,000 feet; it is greater than in districts farther east as the lower part represents some of the basal green beds of those districts.

The upper part is noticeably more sandy, micaceous and chloritic; the marls and sandstones are browner and the former weather differently; there is also a greater proportion of green sandstones and marls and coarse grey grits. In view of the unconformity of the overlying Carboniferous rocks the thickness of this part might be expected to diminish; the opposite appears to be the case, however, and the estimated thickness of 600–700 feet published in the Summary for 1904 is fully maintained if not exceeded. Any overstep that may accompany the unconformity at the base of the Carboniferous must therefore be very small in the ground so far examined. This brings the total thickness of the Lower Old Red Sandstone displayed in the region to close upon 3,000 feet. The width of the outcrop steadily diminishes from about 1½ miles to the south of Narberth to a little over ½ mile near Minwear. This is not due to a thinning in this direction but to a progressive increase in the dip in the southern part of the outcrop, the dip along the base remaining fairly steady at from 65° to 70°.

:. Dixon. Near Freshwater East the red marls, sandstones, etc., of Lower Old Red Sandstone age previously described,* have a thickness

* Summary of Progress for 1904 (*Mem. Geol. Surv.*), p. 41.

of 3,000–3,500 feet and rest sharply on Silurian rocks, there being no basal green series but, on the contrary, a coarse conglomerate in several beds a few feet thick separated by green and red sandstones. Mr. Dixon

The group of conglomerates, also referred to (*loc. cit.*), at the top of the Lower Old Red Sandstone thickens westwards from nothing in Caldy Island to 700 feet near Pembroke. It is still unknown, however, whether this variation is due to wedge-bedding or to overstep by the overlying Upper Old Red Sandstone. The group may be conveniently distinguished, under the name of Ridgeway Conglomerate, from the conglomerates and breccias of the Upper Old Red Sandstone.

In last year's Summary of Progress, pp. 41–42, evidence was adduced in favour of the view that a quartzite-group which occurs constantly at the top of the Old Red Sandstone in South Pembrokeshire, belongs to the upper division of that formation. An examination of Sandtop Bay, Caldy Island, has confirmed this opinion. It has long been known that a bed of clustering tubules, assigned to a new species of *Serpula* by J. W. Salter,* occurs near the top of the Old Red Sandstone in the quartzite-group, and it has now been found that the adjacent strata are calcareous marls and sandstones with lenticles of detrital limestones made up of fragments of crinoids, bryozoa and probably lamellibranchs. They have also yielded two palatal fish-teeth which have not yet been exactly identified, but which are closely allied to Carboniferous forms, not to those in older rocks. It will be remembered that in Skrinkle Haven a marine band containing *Modiola* and *Lingula* occurs at about the same distance below the base of the Carboniferous.† Those fossils alone are not sufficient to prove the affinities of the marine band, but the discovery of the fish referred to leads us to dissociate the group in which the calcareous rocks occur, from the Lower, and to class it as Upper Old Red Sandstone.

CARBONIFEROUS.

Carboniferous Limestone Series. From Ludchurch westwards these rocks occupy comparatively low ground between the Old Red Sandstone and the Millstone Grit. The width of the outcrop diminishes westwards, and near Minwear the base of the Limestone appears to coincide with that of the overlying Grit, although the presence of the former is evidenced by the uneven character of the ground and by occasional sinks. The probable reasons for this diminution will be discussed below. Mr. Jones.

Black shales, weathering olive-green, are exposed in several places between Ludchurch and Templeton. In some cases they overlie coarse ferruginous pebbly sandstone and green gritty shales containing occasional casts of fossils. In a stream east of Templeton and in the road near Mounton farm there occur coarse ferruginous sandstones and micaceous sandy shales closely

* *Quart. Journ. Geol. Soc.*, vol. ix, p. 496.
† Summary of Progress for 1904 (*Mem. Geol. Surv.*), p. 42.

r. Jones. resembling the above, but containing no fossils. They occupy a position approximately where the base of the Carboniferous Series might be expected and may, therefore, be the lower part of the Lower Limestone Shales. On the other hand they are very like the underlying beds of undoubted Old Red Sandstone age. In the absence of more definite evidence it is impossible to say to which formation they should be assigned. In a section in the valley west of Newton farm about 12 feet of strata of this kind immediately underlie the limestone; if these belong to the Lower Limestone Shales they must represent the last remnants of that sub-division.

The limestone is rarely exposed except in quarries. It is a dark-blue rock, partly oolitic with bands of grey oolite. The stone was formerly burnt for lime on an extensive scale, but that industry is dead and the quarries are now worked chiefly for road-metal and building.

A re-examination was made during the year of some of the exposures of the Carboniferous Limestone Series in the light of the recent work of Dr. Vaughan on the fossil zones of that series with a view to determining, if possible, the reason for the disappearance of the limestone in passing westwards. The fossil evidence collected points to two important causes, viz.:—1. An overlap in the lower part of the series; 2. An unconformity in the middle of the series at the base of the "Main Limestone."

In the Summary of Progress for 1903 it was stated that the basal bed of the Carboniferous was sharply marked off from the underlying strata which are of the lithological type characteristic of the Lower Old Red Sandstone. A few feet above the base in the Gellihalog section there is an abundance of fossils which according to Dr. Vaughan are found in other areas at a horizon not lower than the very top of the *Cleistopora*-zone, and might be assigned approximately to horizon β. The representatives of the lower part of the *Cleistopora*-zone and the *Modiola* beds must therefore be either overlapped or represented by a few feet of coarse sediment. Strata of somewhat similar lithological character persist for several miles farther west, but no fossils have been found indicative of a lower horizon. A little more than three miles west of Templeton they probably disappear altogether.

All the exposures in the 'Main Limestone' of this area are in the *Seminula*-zone. The junction with the underlying beds is rather peculiar: it is best seen at the north-east of the Croft quarry at Blaencilgoed. The lowest strata exposed are green, yellow-weathering shales with irregular beds and lenticular pieces of a grey and reddish-grey crinoidal limestone very different from the dark blue limestone above. The two limestones are everywhere firmly welded together, and one might easily conclude that there was a rapid passage from one to the other, as there is a certain amount of alternation of the two kinds.

Closer examination shows, however, that the alternation is due to "inclusions" of the grey in the dark blue limestone. In some

cases the "inclusions" can be removed intact, showing that the junction is not so intimate as would at first sight appear. They are then seen to be of irregular shape with somewhat rounded edges, and resemble slightly the lumps of limestone in the underlying shales. The dark limestone a few inches above the junction contains abundance of fossils characteristic of the *Seminula*-zone. The grey limestone also contains fossils up to the junction, but they indicate a horizon probably not higher than the lower part of the *Zaphrentis*-zone. A junction was also exposed about four miles to the east of the above, and found to be similar in character, except that fossils were not found in the underlying beds, which were of grey oolite. These, however, cannot be a great distance above the base of the Carboniferous in this area. From the fossil evidence at Blaencilgoed there can be no doubt that the two limestones there belong to two different periods, and that they are separated in other areas by a considerable thickness of strata which are not represented in this part of the north crop. In view of the extent of the break the intimate union of the two limestones at the junction is remarkable. At Pendine the corresponding break is accompanied by the conglomerate described in the Summaries for 1902 and 1904. Mr. Jones

Passing westwards the beds below the break diminish steadily in thickness, and, as remarked above, they probably disappear about three miles west of Templeton. It is not certain to what extent the thickness of the beds above the break suffers diminution from below, but it is probable that in addition to the causes already mentioned some change occurs at the base of the Millstone Grit, having the effect of further reducing the thickness from above. More evidence is still required on this point.

Much attention has been paid to the application in South Pembrokeshire of the zones of the Carboniferous Limestone Series (Avonian) established by Dr. Vaughan,* to whom our thanks are again due for assistance in identifying horizons in some important localities. Mr. Dixon

A more exact comparison than was before possible may now be made between the middle and uppermost Avonian of Pembrokeshire and Bristol respectively. In the middle of the series throughout the outcrops of limestone south of the Pembrokeshire coal-field, the *Syringothyris*-zone consists of two divisions. The lower, which is itself two-fold, consists below of grey limestones, either unaltered or more or less dolomitised, and above of comparatively unfossiliferous white oolite, these two corresponding to the *laminosa*-dolomites and *Caninia*-oolite of the Bristol district (*op. cit.* p. 193). The upper division of the *Syringothyris*-zone consists of fossiliferous limestones in which *Bellerophon* is usually abundant. These rocks are succeeded by similar limestones in which *Lithostrotion Martini*, a form which ranges through the upper or Kidwellian division of the series, shortly makes an appearance, whilst *Caninia* and *Syringothyris cuspidata*, forms characteristic of the Clevedonian, or lower

* *Quart. Journ. Geol. Soc.* vol. lxi, pp. 181 *et seq.*

Mr. Dixon. division of the series, still survive. This mingling of the two faunas shows that the limestone in which it occurs belongs to the lower part of the *Seminula*-zone. This subzone was stated in last year's Summary of Progress (p. 45) to be indistinguishable, the mistake arising from the fact that some *Bellerophon*-beds at the top of the subzone were regarded as horizon δ, so that the whole of the subzone was referred to that horizon and the zone below. As the base of the upper part of the *Seminula*-zone immediately above was correctly recognised, there was no room for the lower part between that base and what was supposed to be horizon δ.

Although we still have no knowledge of the top of the limestone and of the beds which immediately succeed it, it has been found that the highest limestone quarried contains some forms indicative of the upper subzone of the *Dibunophyllum*-beds, though the chief fossils, *Dibunophyllum* ψ and *Lonsdalia* have not yet been found. No higher limestone is exposed along the main outcrops, but an anticline near Gumfreston brings to the surface rocks which lithologically and palæontologically resemble the black lias of Oystermouth in Gower. The latter has been recognised by Dr. Vaughan as corresponding to the upper part of the *Dibunophyllum*-zone, and its correlation with the Gumfreston limestone also has been confirmed by him. This subzone is much thinner than at Pendine and Kidwelly on the north crop.

A comparison may also be made between the dolomitisation of the limestone in Pembrokeshire, as far as examined, and other districts. The alteration, which has been extensive only in the lower part of the *Syringothyris*-zone, remains constant on the whole along the strike, but increases in amount northwards. Thus, along the southern limb of the Lydstep syncline dolomitisation is confined to a few beds, whereas along the northern limb it is general for a considerable thickness at the base of the zone, and in the band of limestone north of the Ridgeway its vertical extent is greater still. Here, and to the north of Lydstep, it has profoundly altered the limestone, the product being a fine-grained, grey, saccharoidal rock in which fossils are generally represented by casts. It has also been found that it has affected the rocks on the same horizon in Gower to the same extent as along the northern outcrops in Pembrokeshire. Further east still its effects are widespread in the neighbourhood of Bristol, where it has given rise to the *laminosa*-dolomites,* but in the Mendips,† lying further south, are scarcely perceptible, the change from the district to the north being, therefore, similar to that observed in Pembrokeshire.

Although the zone affected has been subjected to mineralising influences following the pre-Triassic earth-movement, it is difficult to ascribe the change to any of these. For to do so would necessitate the supposition that the dolomites represent rocks which were originally more susceptible throughout to the change

* A. Vaughan in *Quart. Journ. Geol. Soc.*, vol. lxi, p. 193 *et. seq.*
† *Id.* p. 248.

than those on other horizons. That this is not the case is shown by the diversity of original structures in the altered rocks.

On the other hand the wide extent and persistent occurrence of the dolomites point to some agent affecting the whole of a contemporaneous group of rocks over a great area, a condition which would be easily possible shortly after their deposition. And it is significant, in view of the theory that shallow water is a condition favourable to dolomitisation, that the effect increases northwards, in which direction there is evidence in South Wales on the north crop* of upheaval and emersion during the suggested period of dolomitisation.

Millstone Grit.—In the ground surveyed this year the sub-divisions established in the north crop farther east have been found to hold good. Mr. Jones.

The Basal Grit forms comparatively high barren ground south of Templeton, and ranges thence in a direction a little north of west to the Eastern Cleddau west of Minwear. About three miles west of Templeton it is thrown northward nearly three-quarters of a mile by a disturbance ranging nearly east and west, which will be described more fully below. To the west of Minwear a further throw of about a quarter of a mile occurs. The series consists of bands of white quartzite alternating with black shales, some of which have yielded marine fossils. A cutting on the Pembroke and Tenby Railway, a quarter of mile south of Templeton Station, together with the quarry worked for silica-stone, shows the greater part of the series clearly. The quartzite is more abundant relatively to the shales in the lower portion, while in the upper the reverse is the case. The upper limit of the series has been taken at the highest band of quartzite; the base has not been seen. One of the thicker shale-beds contain a thin band crowded with Goniatites; a few specimens occur lower down, while 30 to 40 feet lower is another band containing poorly preserved brachiopods and lamellibranchs. In the quarry a seam of culm from three to six inches thick occurs in quartzite. A few beds of quartzite are exposed in the valley near Carn Mill and again west of Minwear, where they have a north-westerly strike.

Ferruginous quartzite associated with black shales containing abundance of Goniatites have been met with in two well sections. The first is near the main road, a few yards east of the entrance to Molleston Chapel; the Goniatites were found about 25 feet from the surface; the second is 80 yards south of Cotts farmhouse where they appeared to have been only a few feet down. These cases are interesting as showing the gradual approach of the Basal Grit series to the base of the Limestone. The first well is 450 yards south of the base of the Limestone while the second 2½ miles farther west is only 150 yards. South of Templeton the distance from the Goniatite-band to the base

* Summary of Progress for 1904 (*Mem. Geol. Surv.*), p. 44.

Mr. Jones. of the Limestone is over 1,000 yards, but in this case there is probably some repetition of the beds. The thickness of the Basa-Grit is not known with certainty.

The Middle Shales are of the usual character of grey, blue and black shales alternating with grey and olive-green sandstones. These are usually of an even-bedded flaggy type, frequently showing straight dark lines of lamination on a cross fracture. Current-bedded sandstones are rare in the subdivision, which thereby differs from the Coal-measures.

The Farewell Rock which is taken as the uppermost member of the Millstone Grit is an olive-green sandstone, in part even-bedded, in part massive and current-bedded. At the top it generally passes up into the sandy shales of the Coal-measures. Where *débris* only is seen it is difficult to distinguish this rock from sandstones in the higher part of the Middle Shales on the one hand and from those of the Coal-measures on the other. Some further observations on the Millstone Grit will be found in the account of the cliff section near Tenby, given on page

Mr. Strahan. *Coal-measures.*—The eastern part of the Pembrokeshire Coal Field, broadly speaking, has a synclinal form, in so much as the lowest measures, followed by the Millstone Grit and Carboniferous Limestone, come to the surface both to the north and south of it. Closer examination, however, shews that the various sub-divisions lie in normal superposition in the northern side only of the trough, the central and southern parts being complicated by inverted folds and an almost infinite number of large and small overthrust faults. So completely do the superinduced structures dominate the region that it would be easy for a stranger to the Carboniferous system to reverse the sequence of its sub-divisions, for, the prevailing dip being southwards, the Coal-measures appear to dip under the Millstone Grit, and the Grit under the Limestone. The appearance is due partly to inversion, but chiefly to repeated overthrusting from the south.

The direction and distribution of the disturbances leave no doubt as to their belonging to the northern margin of the great Armorican belt, which ranges through Belgium westwards to the south of Ireland, involving the north of France and the south of England. Part of that margin has already been recognised in the Vale of Glamorgan and in Gower, and the disturbances there observed, would if prolonged strike the Pembrokeshire coast near the centre of the syncline, and would fall into line with the general trend of the folds and overthrusts which complicate its southern limb. They commence in Pembrokeshire with a sharp fold which intersects the cliff at Amroth and ranges thence by Begelly towards Martletwy; north of that line there is little or no disturbance of the strata for two or three miles, while south of it the folding and overthrusting increase rapidly in frequency and violence. Lastly the disturbances all show evidence of over-thrusting and overfolding from the south, while cleavage, parallel

to the folding, sets in about four miles south of the northern margin of the belt of disturbance. Mr. Strahan.

In all these respects the disturbances of the Armorican system differ from those which affect the Old Red Sandstone and Ordovician rocks to the north of the coal-field. Those range north of east and link themselves on to the great east-north-east system, to which the folding and faulting of the Vale of Neath, Cribarth, Carreg Cennen, and the Tawe Valley belong. They increase in frequency and intensity northwards, and generally show evidence of overfolding and overthrusting from the north. Cleavage, parallel to the folding, sets in about four miles north of the southern margin of the belt.

It will be seen, therefore, that a part of the coal-field and of the rocks north of it occupies an interval between these two great belts of earth-movement. In that interval there is comparatively little sign of disturbance, and within it for a breadth of about four miles the Carboniferous rocks lie in a normal sequence with a steady dip of 15° to 20° to the south. The interval is narrower in Pembrokeshire than in Carmarthenshire, the two belts tending to meet westwards, but whether they actually will be found to meet is not certain, for the northern belt, curving round from a west-south-west to an east and west direction, becomes more and more nearly parallel to the Armorican belt.

The coal-field is completely dissected by the cliff-section extending from Telpen Point, north of Amroth, to Tenby. Clear though the section is, the interpretation of the structure, and the recognition of the larger overthrusts among the innumerable small slide-planes which traverse the whole sedimentary mass, is far from easy. Certain seams, however, of anthracite and courses of "mine ground" (shale with bands and nodules of clay-ironstone) have been extensively worked and identified at the various outcrops. These and the recognition of the Millstone Grit on either side of the coal-field have served as guides to the general effects of the disturbances.

The following section of the Coal-measures of East Pembrokeshire has been proved in various shafts and drifts in the neighbourhood of Saundersfoot and Stepaside. The records were made many years ago, and it is not known whether any correction was made in them for dip. Probably none was made, and the thicknesses given will average about 8 per cent. more than the true thicknesses measured vertically to the bedding, but the strata have been so deformed by crushing and overthrusting that no precise measurement is possible.

This opportunity may be taken of acknowledging our indebtedness to Mr. C. Vickerman, proprietor of the Bonville's Court Colliery, and to Mr. E. J. Harvey, the agent, not only for giving us access to the plans of the eastern part of the coal-field, but for personally assisting in the examination of the ground.

Mr. Strahan.

Generalised Section of the Coal-measures of East Pembrokeshire.

		Thickness. Yds.	ft.	in.	Depth below Rock Vein. Yds.	ft.	in.
	Measures proved in the Moreton upcast shaft; details unknown	58	0	0	—		
Foxholes Shaft.	Measures with three thin seams	62	0	0	—		
Foxholes Shaft.	Rock Vein of the Timber Vein series	0	3	0	0	3	0
Foxholes Shaft.	Measures	12	0	0	13	0	0
Foxholes Shaft.	Low Vein	0	1	8	13	1	8
Ventilating Pit Bonville's Court.	Measures	17	1	4*	31	0	0
Ventilating Pit Bonville's Court.	Timber Vein	0	6	0	33	0	0
Ventilating Pit Bonville's Court.	Measures	78	2	0*	111	2	0
Ventilating Pit Bonville's Court.	Rock Vein	0	1	0	112	0	0
Ventilating Pit Bonville's Court.	Measures	28	1	0	140	1	0
Ventilating Pit Bonville's Court.	Garland Vein	0	1	3	140	2	3
Ventilating Pit Bonville's Court.	Measures	6	2	3	147	1	6
Ventilating Pit Bonville's Court.	Fiddler's Vein	0	0	6	147	2	0
Ventilating Pit Bonville's Court.	Measures	7	2	1	155	1	1
Ventilating Pit Bonville's Court.	Under Garland Vein	0	1	4	155	2	5
Ventilating Pit Bonville's Court.	Measures	15	0	7	171	0	0
Bonville's Court.	Lower Level Vein	0	1	8	171	1	8†
Bonville's Court.	Measures	26	2	5	198	1	1
Bonville's Court.	Catshole Vein	0	0	8	198	1	9
Bonville's Court.	Measures	44	0	0	242	1	9
Bonville's Court.	Kilgetty Vein	0	1	6‡	243	0	3
Bonville's Court.	Measures	17	0	0	260	0	3
Bonville's Court.	Lady's Frolic Vein		—			—	
Bonville's Court.	Measures	63	0	0	323	0	3
Bonville's Court.	Tin Pits Vein		—			—	
Bonville's Court.	Measures	10	0	0	333	0	3
Bonville's Court.	Farewell Rock		—			—	

Though it is impossible to correlate with certainty the Pembrokeshire seams individually with those of Carmarthenshire and Glamorganshire, we can say that the lower series only of those counties, and probably only the lower half of that series, is represented. The total thickness of measures existing in the eastern end of Pembrokeshire appears to be about 363 yards down to the lowest workable seam, and about 90 yards further to the top of the Millstone Grit, being about 453 yards in all. Measured up from the top of Farewell Rock in the Gwendraeth Valley, this distance would take us well above the Big Vein, but would not include the Carway-fâch and Carway-fawr Veins. It may be further suggested that the Timber resembles the Stanllyd Vein in the soft shales associated with it, while the Rock Vein, with its

* This thickness is based on the information that the Tower Pit of Bonville's Court started in the crop of the Rock Vein, and traversed the Timber Vein at 30 yards and the Lower Level Vein at 168 yards depth. The distance between the Low Vein and the Timber Vein was considerably greater in the Foxholes Shaft.

† In the Moreton upcast shaft the Lower Level Vein lay 200 yards below the Rock Vein of the Timber Vein Series.

‡ The Kilgetty Vein was reached at 96 yards below the Lower Level Vein in the Lower Level Colliery at Stepaside, and at 134 yards below it in the New Hays Pit.

rock-roof, might correspond to the Big Vein. On this view the Lower Level Vein might correspond to the Gwendraeth Vein, and the Kilgetty Vein to the Pumpquart. It will be noticed that 120 yards of measures are mentioned as existing above the Rock Vein. They were proved in the upcast pit of the Moreton Colliery, of which no details have been preserved. It is known, however, that they contained no workable seam, and they may therefore correspond to a part of the barren measures which separate the Big from the Carway Veins in the Gwendraeth Valley. Mr. Strahs

The seams which have yielded the bulk of the coal are the Rock, Timber, Lower Level and Kilgetty Veins. The Timber Vein, though the thickest, suffered from a bad roof, and gained its name from the amount of support necessary. Formerly much mine was worked on or near the coast between Amroth and Saundersfoot, and was smelted at Stepaside. The mine-ground occurred at several horizons, but the best-known courses lay below the Timber Vein (the Kilvelgy Mine-measures); above the Fiddler's Vein, as worked in the cliff east of Wiseman's Bridge, in Lloyd's or the Rooksnest Patch; above the Catshole Vein, worked in the same cliff in the Crichdam Patch; and above the Scad (supposed Kilgetty) Vein as worked in the Burrows Patch, a quarter of a mile west of Amroth. Mine was raised also in the cliff under Hean Castle from measures lying above the Lower Level Vein. The Bridge Patch, which is the first to the east of Wiseman's Bridge, is said to have been in the Fiddler's mine-ground, but the identity of the measures from Wiseman's Bridge as far as Lloyd's Patch is doubtful. Much coal was raised in the neighbourhood for use in the furnaces, but the works were abandoned about 50 years ago, and the coal now being worked is used for local domestic purposes, or for export chiefly as malting fuel. In 1905 two collieries only were raising coal in the eastern part of the coal-field, namely Bonville's Court, where the Lower Level and Kilgetty Veins are being worked, and the Jeffreston Colliery on the Timber Vein.

The coal-field is divided into three or four belts by what are called faults, but which seem to be rather a combination of fold and overthrust. Their effect is to bring up the same measures to the surface repeatedly in spite of the prevalent southerly dip. Thus the first, or most northern, of these is supposed to run from near Amroth by Treberth along the south side of King's Moor and south of Langdon, and though its exact position is doubtful almost everywhere, the fact is proved that along the line indicated there is an upthrow south. The amount of the upthrow was proved to be about 200 yards near Treberth, but it appears to have been only a little over 100 yards at the Woodside Level, 1,000 yards further east, and still less near Amroth, where it takes the form of a crushed syncline and anticline, with the Scad Vein at approximately the same level on either side of it. The belt north of this line of disturbance includes some of the least broken parts of the coal-field, and much coal has been raised from the Lower Level and Kilgetty Veins at Amroth and

Mr. Strahan. Step-aside, and from the higher veins at Begelly and elsewhere.

Mr. Jones. The lower part of the Coal measures is well-exposed in the cliffs between Telpen Point and Amroth as described in the Summary of Progress for 1904.

The lowest coal mentioned in that section is known in the neighbourhood as the Tin Pits, or Ten Pits Vein; it has been dug along the crop near the cliff and in shallow pits near Telpen farm. Indications of a coal at about this horizon have been met with in several places, especially in the valley north of Trewern farm, where it has been worked near the crop by a level and shallow pits.

A band of carbonaceous shale with coal under massive sandstones, which is conspicuous in the cliff at Amroth and is said to have been worked by a level near New Inn, is known as the Lady's Frolic Vein, and has been met with elsewhere. On the east side of the main valley near Trewern it is succeeded by a massive sandstone and has been worked by a level and shallow pits. A few holes on the east of the railway half a mile north of Trewern Bridge were probably on the same vein. North of Thomas Chapel it was got in a few places at about 17 yards below the Kilgetty Vein.

The lowest seam of any importance is the Kilgetty Vein of the Amroth and Kilgetty districts; near Amroth it is said to have been from 20 to 22 inches thick, but near Stepaside only 13 to 14 inches. The crop is seen in the road-bank east of New Inn and again behind Amroth Mill. It rests on the massive sandstone overlying the Lady's Frolic Vein. It is probably this vein which is exposed in the road east of Amroth church, and it is said to crop under Colby Lodge, whence it can be traced without difficulty to near Kilgetty. Near Trewern it meets the Trewern fault, and in the railway-cutting north of that place a vein of coal 3 to 4 inches thick rests on a current-bedded sandstone.

The vein worked some distance to the north must underlie the sandstone at no great depth. These two veins, one immediately above a massive sandstone and the other just below, suggests a correlation with the Kilgetty Vein and Lady's Frolic. From the railway-cutting the upper vein strikes for Trewern House, near which the Lower Level Vein is supposed to crop on the other side of the fault. If the above correlation is correct the fault must be a downthrow to the east of about 120 yards.

North of Thomas Chapel the Kilgetty Vein has been largely worked. It was found at a depth of 156 yards in the New Hays Shaft. North of Carn farm a few holes were put down to it, but no information has been obtained about it in that neighbourhood. On the west side of the Loveston Lake a vein has been worked along and near the crop for about three-quarters of a mile. It is

known as the Islands Vein from the name of the cottages hard by. Mr. Jones.
It is probably the same as the Kilgetty Vein, although the crop on this side of the valley is some distance to the north of that on the east side. The Kilgetty Vein has not been identified farther west; it may be the thin vein dug along the crop near Eweton but between this and the last known point there is some disturbed ground. More evidence is required before a correlation of the veins of Martletwy and Landshipping with those of districts farther east can be attempted.

The next vein of importance is known as the Lower Level, Low Level, or Low Vein. The crop is supposed to range from Stepaside across the Deer Park to the Kilgetty Wood, where it has been worked at the Wood Level and from shafts. To the west of the Wood Level mouth the workings in this vein touched the Newton fault, a downthrow to the west of unknown but probably small amount. Thence the crop runs, as believed, to Trewern, where it meets the fault previously mentioned. On the east of the fault the strike is about north-west, but west of it it changes to due west and old workings occur almost continuously, ranging from the fault through Thomas Chapel and Reynalton to the south of Yerbeston. At the Reynalton Colliery the vein was worked by a slope. From Stepaside to Loveston there is no difficulty in identifying the tips of this vein, as a few casts of lamellibranchs can generally be picked up on them. In a shallow pit 80 yards north-east of the New Hays Shaft at Thomas Chapel, where the vein was met at 22 yards, abundance of these casts were found *in situ* in olive-green shales or mudstones a few feet above the coal. The fossils become gradually scarcer from Hacket westwards, and none were found on the tips of the supposed Lower Level vein of Yerbeston. The workings seem to end near the Waddock Lake. Several veins of coal have been worked beyond this, but the information is incomplete, and it is not yet possible to say which, if any, of them represents the Lower Level Vein.

Near Reynalton and Loveston a seam known as the Catshole Vein occurs some distance above the Lower Level Vein. It is said to be represented by a band of carbonaceous shale and coal resting on sandstone in a quarry near the chapel at Reynalton. It is also seen in the wood east of Loveston, where it has been dug near the crop, and is said to crop a few yards north of Loveston Cross, but nothing further is known of it.

The Kilgetty Vein becomes in places thin and even worthless Mr. Strahan.
in the southern and eastern part of the coalfield, and is then known as the Scad Vein. For example, it occurred in its normal form at Castle Park, Wilson's Pit, and to the north of Newbury, but in the Scad form at the Lower Level Colliery, in the Grove Pit, and at Bonville's Court, as well as in the Burrows Patch in Amroth cliff. In the absence of mining information it would have been difficult to believe in the

Mr. Strahan. identity of the Kilgetty and Scad Veins. Below the Burrows Patch, for example, the following section is open to view:—

Burrows Patch, Amroth.

	Ft.	in.
Scad Vein, about	0	6
Underclay or dunstone	2	0
Grey stone with small nodules of ironstone	2	0
Grey shale	5	0
Rock, weathering white	3	0
Shale with ironstone	15	0
Impure limestone	3	0
Grey shale, seen to	25	0

At New Inn, Amroth, less than a mile east of the Burrows Patch, there are below the Kilgetty Vein some underclay, a few feet of sandy shales, underlain by 30 feet of sandstone, and then a carbonaceous shale with coal-streaks, representing the Lady's Frolic Vein. Below this again come shales with mine.* The sections, therefore, below the Scad Vein of Burrows Patch and the Kilgetty Vein of the New Inn have no resemblance. On the other hand, all attempts to prove the existence of both a Scad and a Kilgetty Vein in one section have failed. In the Lower Level Colliery dunstone and shale with mine was proved to a depth of 31 feet below what was considered to be the Kilgetty Vein without proving any second vein. The Grove Trial Pit was carried to a depth of more than 54½ feet below the Kilgetty Vein, chiefly in shale with mine, with the same result.

The limestone mentioned in the above section is largely composed of the shells of lamellibranchs. It has been determined by Dr. Pollard to be an impure carbonate of iron, lime, and magnesia, with a little phosphate. The residue from acid contains some carbonaceous matter. This band has not been seen elsewhere.

The Kilgetty Vein, where it occurred in workable form, and the Lower Level Vein, have yielded the bulk of the coal in this belt of the coalfield from their outcrop westwards, but at Begelly some of the higher veins, including the Timber Vein, come in, and have been extensively worked. Dipping south-westwards, they crop round the northern and eastern side of the hill on which the village stands. An adit-level, leading westwards, drained off the water to a depth of about 50 yards above Ordnance Datum, but how far below the adit the workings extended has not been recorded. The Trewern Fault, however, ranges along the western flank of the hill, and if, as there is reason to believe, the fault has an upthrow west of 120 yards, it would throw the veins out. The Timber Vein comes in again, however, a few hundred yards west of the fault, and has been patched at intervals towards Langdon.

The next belt of the coalfield includes the cliff between Wiseman's Bridge and Coppet Hall. The Lower Level Vein crops out once, and apparently a second time, in the cliff east of Wiseman's Bridge, in the narrow strip between the Erroxhill

* Summary of Progress for 1904 (*Mem. Geol. Survey*), p. 46.

Fault and the cliff. A more important tract underlay the hill on which Hean Castle stands. The hill, as shown in the beautiful cliff-section, is a structural feature coinciding in form with an anticline, and its sides are dotted over with old shafts, sunk to the Lower Level Vein. The anticline ranges W.25°N., and is accompanied on its north side by a syncline. A shaft in an old brick-yard at Woodside was sunk 84 yards to the Lower Level Vein in the centre of the syncline, and levels were driven in the coal along the north rise of the syncline, round its termination 300 yards north of the castle, and back along the south rise of the syncline almost to the shaft. The workings north of the syncline proved that the vein must come to, or close to, the surface in the Wiseman's Bridge valley. On the other hand, the vein, when last seen east of Wiseman's Bridge, dips so as to gain a great depth in that valley. Between the two, therefore, there is a large downthrow north, which, however, has never been proved in any workings. Presumably it runs parallel to the anticline and syncline described above, under some broken ground north of Wind Hill, and probably near the well sunk to supply Hean Castle where the strata were found to be vertical. A few yards further on it must join the Erroxhill Fault, as proved at Treberth. Mr. Strah

To the south again of the Hean Castle anticline lies the belt in which the Kilgetty and Lower Level Veins are being worked from Bonville's Court. A small but sharp anticline, with the steep plunge down to the north which characterises all the folds of this neighbourhood, serves to define this belt, though it has been crossed in the workings. It ranges W.13°N., and from the southern headland of the bay at Coppet Hall, it runs 100 yards north of Pentlepoir. Though it appears as a sharp fold in the cliff, it was proved in the Lower Level Vein to consist of two parallel fractures, about a chain apart, the northern fracture throwing the vein up southwards 19 yards, while the southern threw it down again southwards 7 yards, the effect being just the opposite of that of two trough-faults.

This belt of the coalfield, ranging from Saundersfoot past Moreton and Jeffreston, includes the principal outcrops of the Timber Vein Series, and contains the nearest approach to an axis in the much-broken syncline. The outcrops, with few exceptions, arrange themselves along a strip of country about one-half to one mile in width, and at first sight appear to run continuously for a distance of about 4½ miles. Closer examination shows this to be far from the truth. No one outcrop runs for more than a few hundred yards, and the persistence of the productive strip is due to repetition of the crops of the same two or three veins by innumerable overthrusts arranged along one general line.

The coal which is thus brought close to the surface in extraordinary abundance has been dug for some centuries, for its working was described as an ancient industry in 1595.* It was

* A MS. of George Owen, 1595. Quoted in a Reprint (1903) of *A Historical Tour through Pembrokeshire*, by R. Fenton, Appendix, p. 343.

Mr. Strahan. said to occur in three forms, as an ore coal, a string, or a slatche. "The ore is the best and is a great vayne spreading everyway, and endureth longest; the stringe is a smalle narrow vayne, sometimes two, three, or four foote in bignes, and runneth downright, and is alwaies found between two rockes. A slatche they call a peece of cole by itself found in the earth, and is quickly digged about, and noe more to be found of that peece."

The digging, or "smutting," as it was called, of this surface-coal, has ceased except for a few small holes opened by the farmers, but enormous depressions and "reens"* (trenches), now thickly overgrown, testify to the amount of coal raised in old days. No written records or plans of the old workings exist, and there are few men now living who saw any of them in operation, but the following descriptions will serve to explain much of what may be seen of them among the old 'rubbish-backs' (shale-tips).

The slant of the Jeffreston Colliery is driven in the Timber Vein, which here has an inclination of about 80°, and is therefore known as a "string." The inclination is southwards, but the fact that the "dunstone" (underclay) lies on the south side of the vein, and the roof on the north side, proves inversion. Accordingly, at a depth of 40 fathoms, the vein curved round to horizontality, and then began to rise northwards, with the dunstone below it. The structure, therefore, is that of a syncline, slightly inverted in its southern limb (the "south rising"), horizontal for a few yards at its axis (the "dead centre"), and dipping normally at about 20° in its northern limb (the "north rising"). At the "dead centre" the coal was nipped out, and continued so for some distance northwards. But the "north rising" itself yielded a large quantity of coal to the old people, in a huge reen which runs to the north of Jeffreston, at a distance of 450 yards from the "south rising." Both to the north and south of this syncline there are other occurrences of the Timber Vein, probably with similar structure, the syncline being merely one of a series. Eastwards and westwards it soon comes to an end, but it is replaced by others in the same general line which together constitute the strip of disturbed ground already alluded to.

A description of a second example at North Park near Moreton, which was worked out many years ago, has been obtained on first-hand evidence.† The Timber Vein, as a "string," was worked in a nearly vertical position to a depth of 20 fathoms, the trench being still in existence 100 yards south-east of North Park Cottage. The workings were carried down to the "dead centre" and a "token" or small leader of coal was followed for about 20 yards northwards but then abandoned, the "north rising" being at Vineyard Cottage, 250 yards further north, as

*The term "reen" is applied also to the ditches by which the Wentloog Level is drained. The Welsh *rhewyn* (drain) has been suggested as the original of the word.

† From Mr. John Thomas, of the Bonville's Court Colliery, who worked in the spot described.

was supposed. The structure, therefore, resembled that of the M Jeffreston example.

Less than 30 yards south of the trench in the Timber Vein there is a depression in the ground marking the site of "old men's workings." When the Rock Vein came to be worked, it was found that the depression was due to a roughly circular mass (or "slatche" as we may suppose) of coal, with a diameter of a few yards and a thickness of about 11 feet, having been dug out. The chamber from which the coal had been removed was discovered in working up a "north rise" in the Rock Vein, and it was ascertained that the mass of coal had formed a part of the outcrop of that vein, repeated probably by a number of small overthrusts. Between this "slatche" and the trench in the Timber Vein there must clearly be a large thrust-fault. Here also the syncline proved in the Timber Vein is only one of several constituting the productive strip.

These two examples will serve to illustrate the kind of structure which prevails throughout the strip of ground under description. For the whole breadth of the strip, thrust follows thrust and the structure of vertical south rising, dead centre, and north rising is repeated again and again. Further than this there are an infinite number of small overthrusts or "overlaps" doubling and trebling the outcrops in a few yards, throughout the ground occupied by the "smuttings." At Moreton and Wooden it is said that there was coal everywhere within the memory of living men. A crop would be "smutted out," but a short driving rarely failed to meet another crop of the same vein close by. The statement is confirmed by the appearance of the ground at the present day.

Under this same ground the Lower Level and Kilgetty Veins are now being worked at a depth of about 150 yards. Of the innumerable folds and thrusts observable on the surface, not one in fifty exists at that depth; only the main folds or faults, which define the principal belts of the coal-field, can be recognised. In order to grasp the significance of this fact it is necessary to consider the general structure of the coal-basin. It is, broadly speaking, a syncline, and the strata in the interior of every syncline must have undergone greater compression than those in the outer curves. Again the syncline is asymmetrical, in consequence of the thrusting-up of the strata in its southern limb. This asymmetry is reflected in the form taken by the outcrops in the strip described above. Thirdly, the thrusting was not only northwards but upwards, a fact shown by the inclination of the thrust-planes and by the tendency of older strata to override newer strata towards the north, and for this reason the planes of movement which affect the southern limb tend to emerge at the surface in the centre of the syncline. Lastly, the rocks lying below the productive belts include such formations as the lowest Coal Measures, the Millstone Grit, Carboniferous Limestone and Old Red Sandstone. It is safe to assume that these massive formations, apart from the fact that they occupy the outer curves of the syncline, would show deformation on a broader scale than the soft strata associated with the Timber Vein series.

Mr. Strahan. The coast-section in which many of the structures described above are clearly exhibited deserves special attention. An impression is gained from a cursory glance that a southerly dip prevails throughout, but it will be found that the effects of the dip are counteracted, firstly by a succession of anticlines all presenting vertical or inverted faces to the north and slanting more gently down southwards, the effect being the same as that of an upthrow south, or of an overthrust from the south. In addition to these there are several large overthrusts from the south, some of which follow the bedding approximately and are not easy of detection. Lastly, close examination shows that there has been great deformation of the whole sedimentary mass by movement along bedding-places and along innumerable slide-planes subsidiary to the main overthrusts, and by the "streaking-out" of some of the more plastic, as well as the crushing of some of the less yielding strata. Coal-seams and carbonaceous shales were among the first to yield and to permit of movement between beds, the result being that what was once a seam with partings has been ground up into a schistose layer of variable thickness with no definitely recognisable coal in it. These black and greasy layers are known by the miners as "dilsh," and the finding of a coal-seam in the condition of dilsh is a serious risk in this coal-field.

An account of the lowest Coal-measures east of Amroth was given in the Summary of Progress for 1904, p. 46. To the west of Amroth the disturbances begin. Some sharp folds with much crushing, which constitute the disturbance known further west as the Erroxhill Fault (p. 53), are intersected by the cliff at Cliff Cottage. The Scad Vein, representing the Kilgetty Vein as supposed, crops in the hillside north of the disturbance and in the cliff south of it at about the same level. In the cliff it runs at the foot of Burrows Patch and on the top of the strata containing the limestone referred to on p. 56. Two courses of mine were worked. The lower, or Kilgetty slate-mine, was opened in a row of levels in an undercliff and descends thence to the beach 270 yards east of a ruined yard where the mine used to be stored. A pretty S-shaped fold and thrust are shown in the rock above the mine, and two normal faults ranging N.13°E. with downthrows eastwards of 10 and 5 feet respectively, cut through the whole series of beds, right through the east and west structures. Just above the brow of the cliff the Catshole mine-ground was worked by a row of levels. This ground rests on the Catshole Vein, which is here about 8 inches thick, and was loosened by the removal of the coal below it, before being worked. These strata come down to the beach at the ruin mentioned.

The Lower Level Vein comes down 100 yards further west. Its identification is placed beyond doubt by the occurrence of lamellibranchs in the roof, by recognition of a band of ironstone known as the "constant leader" 2 feet above the coal, and by a thin band of carbonaceous shale, known as the Lower Level "grist," which lies about 20 feet above the coal. The Fiddler's Vein follows in normal sequence and has been dug in the fore-

shore 280 yards west of the ruin, while the mine-ground which lies upon the vein was worked in the cliff above, in Lloyd's Patch. Mr. Strahan

Thus far the sequence, in spite of numerous small thrusts and broken folds, is clear, but from this point to Wiseman's Bridge there is much doubt about the recognition of the strata. The dip continues south-westwards at 15° to 20°, locally rising to 50°, yet the Lower Level Vein is said to crop out again 200 yards south-west of Lloyd's Patch, and the Fiddler's mine-ground is said to have been worked in the Bridge Patch. If these identifications are correct, there must be a large overthrust on the west side of Lloyd's Patch, concealed by its almost following the bedding, but repeating the Lower Level and Fiddler's Veins. Attempts have been made to confirm the identification, but up to the present without success, owing perhaps to the landslipping and confusion caused by the old workings.

The remainder of the cliff as far as Wiseman's Bridge shows strata with many small overthrusts and undulations, but with a prevailing dip to the south-west. It was believed that the Rock Vein (the lower vein of that name mentioned on p. 52) occurred above the Bridge Patch, and a vein is visible in a headland 180 yards east of the Public House. A massive rock above it suggests that it may be the Rock Vein, but a fault of unknown amount throws the vein out of sight within a few yards.

Here the Stepaside valley opens out on the shore. At low tide the south-westerly dip prevailing in the cliff can be observed in the foreshore to increase steadily to a high angle to a point nearly south of the Public House. The inference seems to be inevitable that the Lower Level Vein must here gain a great depth. Yet on the other side of the valley there is proof that that vein must be near the surface at this same point.

The proof was obtained in a shaft sunk at the old brick-works. It reached the vein at 84 yards depth in the centre of a small syncline as described on p. 57. The rise on the north side of the syncline was not recorded, but judged by what can be seen on the surface the dip must have ranged from 20° to 45°. The vein therefore should crop out at a distance of about 200 yards north of the shaft, near the very spot at which it has been inferred to lie at a great depth. Nothing is known of any fault to which this effect could be attributed, but it must be supposed that it runs parallel to the syncline on the one side, and to the fault at the Public House referred to above on the other, and that it must pass just north of the workings from the Woodside Shaft. This course would take it a little south of Harry's Tump and close by the well sunk to supply Hean Castle, where, as a fact, the strata were found to be vertical. Near here it should join the Erroxhill Fault, but its course and even its existence become problematical.

The syncline found in the shaft is succeeded by the Hean Castle anticline. The Lower Level Vein comes up in the foreshore 200 yards south of the shaft and passing over the anticline descends again 300 yards further on, at a point 80 yards north

Mr. Strahan. of the end of a tunnel on the mineral railway. The anticline pitches seawards and the crops run continuously from side to side of the bay across the foreshore, as well as along the face of the cliff, each soft bed being indicated by a strip of sand. The broadest strip corresponds with the crop of the vein, but the coal has all been dug away between tides. The measures above it, however, are well placed for examination and the various characters noted on page 60 serve here also to identify the Lower Level Vein. A thin seam, probably corresponding to the lower Garland Vein, crops out above it, and above this again a massive sandstone, which forms headlands on both sides of the bay. Though upwards of 80 feet thick this rock is not recognisable elsewhere.

No fault underlies the alluvium of the Coppet Hall valley on the south side of this anticline, but there is a sharp anticline visible in the headland south of the valley, and in the foreshore. The anticline presents a form common to all the folds from this point onwards, namely, a gentle rise from the south and a steep plunge down to the north. Such a structure suggests pressure from the south and may be regarded as a first stage in the formation of an overthrust from that direction. In the underground workings this anticline appeared as two parallel faults with a wedge of ground pushed up between them (p. 57). From this point southwards the strata follow in natural order with a southerly dip as far as the harbour, and according to old plans the Timber Vein crops out under Saundersfoot. Nothing is known now of any such crop.

At Saundersfoot Harbour this belt of the coal-field comes to an end. An extremely sharp anticline forms the cliff on the south side of the harbour, with its northern limb vertical as usual. It brings to the surface sandstone shales and mine-ground with some small seams of coal, known as the Stammers or Steeping Veins, which were formerly worked in Road Wood, the Swallow Tree Valley, and by levels in the cliff. According to a report by Messrs. Foster, dated 1845, two veins of coal occurred with six courses of mine-ground. The uppermost or Yard Vein varied from 1 foot 6 inches to 2 feet in thickness, and the Coaly Vein, 66 feet below it, was 1 foot 8 inches thick. The workings were carried to a depth of 90 feet below the sea, and were limited to the ground lying east of the Swallow Tree stream.

It was suggested that the Stammers Veins corresponded to the Fiddler's and Garland Veins. If this were the case it would mean that the Lower Level and Kilgetty Veins might be expected to occur under the same, or rather more than the same, area. The suggestion, however, has not been borne out by more recent observations. That the productive measures of the Bonville's Court belt appear to dip under the Stammers Veins is discounted by the fact that the effect of the dip is more than counteracted by the folding and overthrusting. A cursory glance at the cliff-section from Saundersfoot westwards might lead to the inference that newer strata are continually coming on in that direction, which we know to be not the case.

Secondly, it is curious that the Lower Level and Kilgetty Veins have not been found either in the cliff or inland, if the Stammers Veins correspond to the Fiddler's and Garland Veins, for according to the table given on p. 52 the Lower Level Vein is only 28 yards below the Fiddler's Vein. Mr. Strahan

But the supposition that the Stammers Veins lie below the Kilgetty Vein is not wholly free from difficulties, for they must in that case correspond to the strata which crop at Amroth and Telpen, which they do not very closely resemble. It is necessary also to suppose that there are other disturbances besides the one known as the Harbour Fault, for this passes north of some old workings in the Timber Vein. The main fault must pass between the Timber Vein workings and those in the Stammers Veins in ground not yet examined. Some sharp folding and complicated overthrusting in the cliff about 200 yards south of the Harbour Fault leave no difficulty in supposing the existence of such a fault.

The southern limit of the Stammers Veins is more difficult to determine. There are no workings on them south of the Swallow Tree stream, though there is no obvious fault to throw them out. Possibly they are too deep to be worth getting, but it seems likely also that they deteriorate southwards, for they do not present themselves in a workable form on either side of the Monkstone anticline nor in the cliffs south of it.

The region occupied by these lowest measures has a breadth of a little over a mile. As displayed in the coast-section it presents a series of sharp anticlines, all vertical or inverted in their northern limbs, so as to present the appearance of tumbling over towards the north. Including the Harbour Fault, four such anticlines occur north of the Monkstone in a distance of about half a mile. The Monkstone Headland itself is a compound anticline, at least two sharp folds occurring about seventy yards apart and together forming the fifth anticline. Three hundred yards south of it we reach the sixth anticline, a magnificent arch inverted in its northern limb, and presenting some small coal-seams with underclays above them and their roofs below them. From this anticline southwards for about 650 yards there are no large disturbances and the dip diminishes to about 10° seawards, so that the bedding as seen from the sea appears nearly horizontal. The thin seams of coal mentioned above descend to the sea-level on the south side of the anticline and pass under these gently inclined strata.

A rocky headland characterised by this gentle dip is situated 700 yards north of the Waterwynch inlet. Between it and the inlet we pass on to strata which are assigned to the Millstone Grit on the strength of their containing *Pterinopecten* and Goniatites, and of their general resemblance to the Millstone Grit of Marros and Telpen. The structures which bring about this succession in spite of the dip are of extreme interest and fully exposed to view.

There are two bays between the headland and the inlet. In

Mr. Strahan. the first (more northern) the gently inclined measures turn abruptly up to a vertical position and the thin coal-seams and some mine-ground with them reappear and run 50 or 60 feet up the cliff. Here they quickly turn over and become involved in a maze of contortions and slide-planes. Every step southwards the confusion increases, until the whole mass of strata assumes the condition of a crush-rock, composed of disjointed and twisted fragments ranging from a few inches to 8 or 10 feet in length. The crush-rock includes about 100 feet of strata and forms the lower part of the cliff for upwards of 150 yards.

On rounding a small headland and entering the second (more southern) of the two bays we see that the upper surface of the crush-rock is formed by a clean-cut slickensided plane, slanting down southwards at an angle of about 15° and passing below the beach about the centre of the bay. Upon it and parallel with it rest shales and sandstone, apparently undisturbed, and contrasting strongly with the jumble below it. Examined more closely, however, these rocks also show the effect of movement, for certain bands in them, though following the general stratification, have assumed the condition of "crush-rock." One such band, about 10 feet thick, is well shown in the southern point of the bay and on the ledges towards Waterwynch, where a thinly and evenly bedded sandstone has been broken up and recemented.

These facts strongly suggest that the slickensided plane is the floor or "sole" of a powerful overthrust, and on investigating the relative age of the strata above and below the plane we get strong confirmatory evidence. The strata below it, with their thin coals and shales, are certainly Coal Measures, and presumably correspond to the measures lying below the Kilgetty Vein in the neighbourhood of Amroth; the strata above include evenly bedded, almost laminated, sandstones which resemble parts of the Farewell Rock near Telpen, and quartz-grits and conglomerate; with these are interbedded shales with two or three bands of structureless mudstone in which Goniatites and *Pterinopecten* abound. Locally those fossils have considerable significance, for they have been found in South Wales in the lower part of the middle subdivision of the Millstone Grit but not higher. The inference follows that the middle part of the Millstone Grit has been thrust on to the top of some of the lowest Coal Measures.

The slickensided plane is accompanied by some subsidiary planes branching from it, but is so clear and regular in the second bay and in the top of the headland separating the two bays that no difficulty would be anticipated in tracing it across the first bay. As a fact, however, the strata above it turn up to verticality in the top of the cliff of the first bay, and though they do not fit on to the crumpled measures in the lower part, it is difficult to detect a definite plane between the two. The cliff is inaccessible and can be viewed only from a distance.

The next bay south of Waterwynch gives an equally good view of another overthrust which, however, is inclined at an angle of

42° from the horizontal. The sandstones and shales with Goniatites, dipping steadily southwards under Waterwynch, are brought by it into contact with a considerable thickness of shales with Goniatites at more than one horizon and abundant plant-remains, interbedded with ripple-marked sandstones and some quartz-grit. These strata occupy a distance of 270 yards and appear to dip southwards at about 70 degrees. As a fact, they are all inverted, as will be ascertained on reaching Bowman's Point, where they become vertical and then arch over in a broken and compound anticline to a normal southerly dip. The effect of the overthrust, therefore, is to throw an inverted series into apparently conformable sequence with strata that are not inverted. To the south of the Bowman's Point anticline the strata which are inverted north of it follow in reverse order. Mr. Strahan.

The goniatite-bed mentioned above descends to the foreshore in First Bay, as was mentioned in last year's Summary of Progress, p. 46. The thick sandstones some distance above reach the base of the cliff in their turn, but are immediately bent up again into a slightly inverted position at First Point, forming, therefore, a sharp syncline of which the axial plane dips steeply southwards. The beds below, which should reappear in the cliffs to the south, have not been recognised there. Probably a strike-fault cuts them off at a short distance from First Point, for the section beyond exposes shales with various lamellibranchs but no goniatites, which cannot be correlated at present with any part of the series outcropping to the north. These shales in their turn appear to be folded synclinally and inverted near the Gosker Rock, a short distance south of which the limestone is brought on by the Ritec fault (*op. cit.* p. 50). Mr. Dixon.

FAULTS AND DISTURBANCES.

Some general remarks on Faults and Disturbances, together with a more detailed account of the remarkable structures observable in the coal-field, will be found in the account of the Coal Measures given on pp. 60–65. The following notes describe the principal disturbances that have been encountered during the year on the north and south sides of the coal-field. Mr. Strahan.

In the neighbourhood of Whitland the general strike of the beds is approximately east and west, and nearly all the faults and thrusts take the same direction. The anticline described in last year's Summary* as the Llanllwch-Llangynin anticline has been traced westward to the north of Whitland and Llanfallteg, where it is complicated by subsidiary parallel folding. The cleavage is almost restricted to the northern limb, while the southern limb is often locally inverted. Messrs. Cantrill and Thomas.

Several strike-faults and thrusts with low dip towards the north accompany the dome-like anticline of Henllan and the main anticline of the district. Mr. Thomas.

* Summary of Progress for 1904 (*Mem. Geol. Surv.*), pp. 34, 47.

Mr. Thomas. The Bala Limestone of Ty'n-coed is faulted off on both sides, on the one side against *Dicranograptus* Shales, and on the other against Redhill Beds. The more northerly of the two faults probably continues westward towards Clynderwen under the drift, throwing *D. bifidus* Beds against Redhill Beds.

Mr. Cantrill. The belt of faulting along the outcrop of the *D. bifidus* Beds at Llangynin has been traced north-westwards into the Fenni valley; it appears to consist chiefly of repeated overthrusts from the north.

Another belt has been followed westwards from Clog-y-frân towards Whitland. There it divides into branches, one of which runs along Cwm-waun-gron, faulting *D. bifidus* Beds against Lower Llandovery, while another follows the Tâf from Whitland north-westward past Trewern, separating *Dicranograptus* Shales on the south from *Tetragraptus* Beds on the north.

A well-marked anticlinal axis with east and west range underlies Lampeter Vale west of Whitland; the core is occupied by *D. bifidus* Beds, from which the Llandilo Flags and Limestones dip away on both sides. To the north of the anticline lies a faulted syncline the axis of which ranges through Commercial, three miles west of Whitland. The beds involved include the Redhill and Slade Beds and an outlier of Lower Llandovery at Wheelabout. To the south of the anticline a well-marked syncline underlies the village of Lampeter-Velfrey.

Mr. Jones. To the south of the village the Ordovician rocks take the form of an anticline ranging nearly east and west and pitching west. The south limb is inverted in places to the extent of 50°, and cut by strike-faults which are powerful downthrows to the south. The anticline is also evident in the Lower Llandovery rocks near Blackalder. The base of the Old Red Sandstone has been affected by a movement having a like direction, as is indicated by the vertical or very high dip along the base, and the gradual diminution of the dip towards the south. North of Minwear a fault having a west-south-west direction throws the base to the north; this fault appears to be continued in a downthrow to the west which traverses the Carboniferous rocks in a south-south-west direction.

In the Summary of Progress for 1904 it was said that the Red Roses Disturbance showed a tendency to take an east and west direction near Ludchurch. From that place it proceeds in a direction a little north of west for about four miles. Near Templeton the presence of a disturbance is suggested by the frequent displacement of the base of the Carboniferous. The width of the outcrop of these rocks in that neighbourhood is probably due to repetition either by strike-faulting or folding or both. About three miles west of Templeton the disturbance has the effect of a downthrow to the north duplicating the outcrop of the Carboniferous rocks for about a mile. Its further course is not certain; about a mile east of Martletwy the lower Coal Measures are shifted northwards by some sharp anticlines and synclines, and a similar state of affairs is seen west of the church at Martletwy. If these folds

form part of the Red Roses Disturbance this must have resumed the west-south-west direction which it had several miles to the east. Mr. Jones.

A few faults having a northerly or north-easterly direction traverse the northern part of the coalfield. The most powerful of these is the Trewern fault which is an easterly downthrow estimated at 120 yards. The other faults having this direction are of little importance.

The Ritec fault mentioned on p. 50 of last year's Summary of Progress has now been traced as far as Pembroke Dock. Throughout its course it has a considerable downthrow to the north, and, though nowhere exposed, it is probably an overthrust like many of the strike-faults exposed in the cliffs. From Tenby westwards almost to Flemington it throws, as a rule, the *Zaphrentis*-zone of the Carboniferous Limestone against 'Millstone Grit' on the north. It then crosses the limestone-outcrop and, in a short distance, brings up the Lower Old Red Sandstone on the south side against Carboniferous Limestone on the north, continuing thus as far as it has been followed. Mr. Dixon.

To the south the next great break, the Ridgeway fault (*loc. cit.*), which at Penally throws Lower Limestone Shales against *Seminula*-beds, passes westwards into a broken syncline lying to the south of a complete zig-zag fold, of which the middle limb is formed by the belt of inverted beds described last year. The syncline forming the northern half of the zig-zag, when traced still further westwards, itself passes into a fault having the same direction and throw as the Ridgeway fault but not quite in line with it. Thus we see how two faults which replace one another *en échelon* may be connected together by an intermediate fold.

At Hays the more western of these two faults has the effect of bringing beds below the Ridgeway Conglomerate against Upper Old Red Sandstone, the throw, therefore, being at least several hundred feet down to the north. Further west it passes into an unbroken syncline which eventually dies away.

It has been found that the outlier of 'Millstone Grit' which runs westwards from the coast at Lydstep Haven does not terminate at Norton as shown on the old map (sheet 38) but is only shifted there northwards, about 400 yards, by a north-north-west fault. On both sides of the fault it forms a ridge overlooking the limestone-country to the north and south. By this means it may be easily traced past Jameston, west of the fault, to the longitude of Manorbier Newton. There it rapidly narrows and ceases to form a dominating feature, but is marked on the contrary by low, wet ground. Its termination has not been actually traced, but is probably close by.

The north-north-west fault mentioned above may be traced southwards from Norton past Manorbier by means of its effect on the outcrops of the Lower Limestone Shales and the various divisions of the Old Red Sandstone, but still further south its course is not so clear, though it remains to be seen whether

Mr. Dixon. it does not continue to the sea. But though it has so profoundly affected the outcrop of the 'Millstone Grit' it produces little or no displacement in the boundaries of the Upper Old Red Sandstone lying in the direction in which it points to the north. To the east the various formations lying between the Lower Old Red Sandstone and the 'Millstone Grit' are also normally displayed, showing that the fault does not turn off in that direction. But to the west *Seminula*-beds are exposed near Rock within such a short distance of the outcrop of the Lower Limestone Shales as to make it certain that a considerable thickness of the lower part of the limestone is faulted out there. But although this fault follows the strike of the rocks (and in fact, without the evidence of the zoning, would remain unsuspected), we are driven to conclude that it is the continuation of the Norton fault which accordingly must change its direction suddenly from north-north-west to slightly north of west. This variation in direction of a fault is of interest as probably all the faults in the district having the latter direction are pre-Triassic, whereas some at least of the north-north-west set are post-Triassic. But in the case we are considering it would seem that although the two parts of the fault differ considerably in direction they were produced by one movement. For in the north-north-west fault the shift is chiefly lateral, and, relatively, northwards west of the fault, as is shown by the displacement of the vertical beds affected, whereas the strike-fault, judged by its effects, is probably an overthrust dipping south at a lower angle than the bedding. These facts are in accordance with the supposition that the block of country in the angle of the fault has moved bodily northwards, relatively to the ground north and east of it.

GLACIAL.

Mr. Cantrill. In the neighbourhood of Whitland nothing of the nature of boulder-clay has been met with, the bottoms of the valleys being occupied only by debris and rainwash which slopes uniformly down from the steep sides. A small patch of true boulder-clay, however, lies on the south side of Lampeter Vale half-a-mile east of Lampeter Velfrey. Its glacial origin is evidenced, not only by the mixed character of the materials, but by the occurrence of small fragments of Old Red marl which could not have been transported under the present drainage-conditions. This drift is exposed in Cwt-y-barkit Lane.

Farther west, a small patch of fine gravelly and loamy boulder-clay containing debris of Lower Llandovery sandstone, various Ordovician rocks, and Old Red Marls has been cut through by the Whitland and Tenby railway half-a-mile south of Llanddewi Velfrey; it lies some 40 feet above the adjacent river Marlais.

Besides these two small patches of drift, numerous large boulders of igneous rocks, ranging up to 7 feet long, lie scattered over the surface, especially about Lampeter Velfrey. They are mostly of ophitic diabase and indicate a westerly or north-westerly origin. Similar boulders occur on the eastern end of

the Llanddewi ridge near Trewern, and at Llangan, north of the Tâf, but do not extend as far east as Whitland. Mr. Cantrill.

No deposit that could be identified as boulder-clay has been seen in the ground lying north of Whitland, but near Henllan Amgoed large boulders of ophitic diabase and less frequently of ash make their appearance and become more numerous westwards. Near Castelldwyran the boulders are abundant and have been largely used for gate-posts. Some have been noted containing as much as 75 cubic feet. Mr. Thomas.

Thick deposits of gravel extend along the ridge between Castelldwyran and Llanfallteg church, towards Clynderwen, around which village they spread out both northwards and southwards.

From Templeton to the Eastern Cleddau the drift is almost confined to the hollow occupied in part by the Lower Carboniferous rocks. It is a yellow sandy clay containing fragments of basal Millstone Grit and Old Red Sandstone. Large boulders of a quartz-conglomerate and rounded quartz-pebbles are frequent between Templeton and Cross Hands. They were probably derived from the band which occurs in the lower part of the Old Red Sandstone. Around Templeton there is a thin deposit of gravelly drift with far-travelled boulders as well as abundance of Old Red Sandstone fragments. This deposit follows roughly the line of the hollow occupied by the railway from near Cold Blow for about three miles to the south. Mr. Jones.

From Thomas Chapel and thence along an approximately east and west line to Tedion Mountain great numbers of boulders of Millstone Grit occur on the higher ground which is otherwise free from drift. Some of them are of large size and they were once so abundant near Tomlas Hill and Rock Farms at Thomas Chapel as almost completely to cover several acres of ground. This may perhaps represent a marginal deposit of the ice, especially as there is as yet no conclusive evidence of glacial deposits immediately to the south.

In the valleys and hollows throughout the district there is often found a yellow clay charged with rather angular boulders. It never appears to be thick and seldom contains any material that can be proved to be of distant origin. Its margins are generally indefinite, for it shades off on one side into clay-soil, undoubtedly derived from the decomposition of rock-in-place, and on the other side gives on the streams or on a small alluvial flat. Its mode of occurrence is suggestive in some respects of a glacial origin, and the fact that foreign boulders do occasionally occur in it lends some support to that view. There is no difference in its mode of occurrence in passing south of the line of Millstone Grit boulders mentioned above though as yet no undoubtedly foreign fragments have been found far in that direction. The boulders are chiefly of sandstone which may have travelled but a very short distance, but on the other hand may have come from afar. Near the line of Millstone Grit boulders the clay in the valleys is charged with that material for at least half-a-mile to the south, but this, of

Mr. Jones course, as well as the clay, may have been introduced from the higher ground. There is, therefore, some doubt as to the direct glacial origin of nearly all such deposits in the district. They are distinctly older than the Alluvium, for the streams have cut into them to form the alluvial flats.

Mr. Dixon. Thin patches of boulder-clay and glacial gravel, in which typically glaciated fragments occur, have been found in protected positions along the Sageston valley, between Carew and the northern foot of the Ridgeway near Coppybush, along the southern foot of the Ridgeway between Bubbleton and Manorbier Newton, and on Caldy Island. In places the material has sunk into pipes in the Carboniferous Limestone, some of which are still connected with patches on the surface, while many more are now isolated by erosion.

It is not known, however, to what extent the infillings of a pipe thus isolated are glacial in origin, though in the case of a large one exposed in the cliff of Sandtop Bay, Caldy Island, they include many rocks not found *in situ* either on the island or on the adjacent mainland, and, in some cases, are facetted and scratched.

The chief characteristic of these glacial deposits is the presence in them of frequent fragments of igneous rocks, of which the origin is, as yet, unknown.

It is of interest that at Bullum's Bay the glacial gravel appears to overlie the raised beach, though the exposure is obscure and the evidence of superposition is not so conclusive as in Gower.*

RECENT AND POST-GLACIAL.

Strahan. The foreshore opposite Amroth and for a short distance westwards is formed of a blue clay with the stumps of trees rooted in place, and with many prostrate trunks and branches. A similar deposit occurs opposite Wiseman's Bridge, and was formerly used, with clays from the Coal Measures, in the brickworks at Woodside. It is reported that when the patches were being worked, there was a considerable tract of foreshore above high-tide mark, and the rumour is partly confirmed by the fact that the ore was carried along a road at the foot of the cliff. though now the cliff is reached by every tide. The remains of the same submerged surface were noted in the Summary of Progress for 1903, p. 52, and a similar forest is well shown at low tide in Swansea Bay. Oak and alder make up the majority of the trees.

ECONOMIC GEOLOGY.

Cantrill. Rough building-stone is occasionally obtained from grits in the *Tetragraptus*-beds, from the ashes in the *Didymograptus bifidus*-beds, from the Llandilo Limestone of Lampeter Velfrey,

* R. H. Tiddeman, Summary of Progress for 1899 (*Mem. Geol. Surv.*), p. 155.

and from the Bala Limestone of Fron and Trewern near Llanddewi Velfrey. A small quantity of stone is got for the same purpose from the green sandstones at the base of the Old Red Sandstone at Cafan-côch, south of Whitland. But the best building-material in the neighbourhood of Whitland is got from the Lower Llandovery Sandstones at Pen-y-back. Mr. Cantrill.

Roadstone is got from the Carboniferous, Llandilo, and Bala Limestones.

Lime was once extensively burnt at Lampeter Velfrey (Llandilo Limestone), and to a less extent at Fron and Trewern (Bala Limestone), but this is no longer done.

Bala Limestone was formerly burnt at Ty'n-coed, west of Hendre, and the impure *Dicranograptus* (Mydrim)-limestone at Castellgorfod, north of St. Clears. Mr. Thomas.

Building-stone is obtained from some quarries in the upper part of the Old Red Sandstone near Narberth, from the Carboniferous Limestone, and occasionally from some sandstones in the Coal Measures. Mr. Jones.

The chief source of the road-metal of the district is the Carboniferous Limestone of Ludchurch and Templeton; many large quarries formerly worked for lime-burning are now exclusively worked for this purpose.

Silica fire-bricks are burnt at Templeton, the raw material being obtained from quarries in the lower part of the Millstone Grit.

The water-supply is chiefly obtained from springs and dip-wells, but draw-wells are not uncommon in the Templeton district.

Building-stone and road-metal are obtained for local purposes from the Carboniferous Limestone. A few small quarries have been worked in the Old Red Sandstone, but are now disused. Mr. Dixon.

The large Blackrock Quarry near Tenby, formerly worked for lime, now supplies ballast for the Great Western Railway. An adjacent sand-pit formerly yielded blown sand for sanding the metals on that system.

Lime is little burnt now, only one kiln, near the Blackrock Quarry, being in constant use. From the large High Cliff Quarry on Caldy Island, however, a considerable quantity of raw limestone is sent away, chiefly to Devon, to be burnt.

Ironstone (limonite) has been wrought at several places to a small extent from more or less irregular deposits in or near the limestone.

The areas underlain by limestone are dry, except where the surface descends to the saturation level. Much water, however rises in the Old Red Sandstone, the junction of the Upper and Lower divisions being marked by many springs. From some of these St. Florence and Pembroke derive their supplies.

II.—PETROGRAPHICAL WORK.

Dr. Flett.

The principal work undertaken by the petrographer during the year 1905 has been the preparation of chapters on the petrographical material collected from areas which have been mapped and on which memoirs are shortly to be published. With Mr. Barrow he has examined a suite of specimens from the Scilly Isles, and the results are incorporated in a memoir which is now passing through the press. Several months were spent during the summer in studying the large Survey collections of rocks from the Midlothian district. It is hoped that the revision of the petrology of this important area will be completed during 1906. The Plymouth sheet, which has been mapped by Mr. Ussher, contains many igneous rocks, principally schalsteins and diabases of Devonian age. A special account of the microscopic features of these rocks has been prepared by Dr. Flett for Mr. Ussher's memoir.

In answer to enquiries received from the field officers and from outside sources the petrographer has issued reports on 489 Scottish and 420 English rocks. Dr. Teall has examined the collections made from the Mevagissey district in Cornwall for Mr. Clement Reid, and has continued his investigations on the Lewisian rocks of Scotland, principally those from the Glenelg area. Mr. Harker has undertaken the whole petrology of the Tertiary volcanic rocks of the West of Scotland, which have been mapped. Professor W. W. Watts has given valuable assistance with the petrography of the Midlands, including the rocks examined for Mr. Fox Strangways' Leicestershire memoir. Mr. Thomas takes charge of all the petrographical work needed for the memoirs on the revised mapping of South Wales. Mr. E. B. Bailey has drafted an account of the igneous petrology of the East Lothian area, which will form a chapter in the memoir on that sheet, shortly to be published. Mr. Bailey, Mr. Grabham, Mr. Anderson and Mr. Muff spent a part of the winter season in the London office engaged in the study of the microscopic sections prepared from the rocks of the districts which they have mapped during the summer.

In July Dr. Flett spent two weeks in Scotland examining certain exposures near Edinburgh and Oban in connection with petrographical problems requiring further elucidation.

On account of the large amount of current petrographical work it has not been found possible to devote much time to the museum collections. Mr. Rhodes has cleaned and re-catalogued the rocks from the English Lake district and Mr. Thomas has, where necessary, revised the nomenclature. The principal addition to the collection is a suite of 142 trimmed specimens of Cornish rocks obtained by Mr. T. C. Hall. These will shortly be placed on exhibit along with other material to illustrate the geology of the districts which have been recently re-surveyed under Mr. Clement Reid. Mr. Hall has also taken 128 negatives of geological subjects in Cornwall which will be used to illustrate memoirs and for exhibition in the museum.

III.—CHEMICAL WORK.

During the first three months of 1905, the old Laboratory in the London Office was vacated, and the Chemical department transferred to a more commodious suite of rooms in the new office. The time spent in removal was partly employed by Dr. Pollard, with the assistance of Mr. MacAlister, in assaying various ores from Scotland and from Cornwall. Dr. Pollard

The remainder of the year has been occupied in rock analysis and in a discussion of the results of all the reliable analyses of South Wales Coals, including those made in the Survey Laboratory. Owing to pressure of work it was found impossible to overtake all the analytical work required, and eleven samples of Coal were analysed by Mr. C. A. Seyler, B.Sc., F.I.C., Public Analyst for the Counties of Carmarthen, Glamorgan, Pembroke, and the County Borough of Swansea.

The following are the principal analyses which have been made during the year. Further particulars of the nature and mode of occurrence of the rocks will be found in the respective Memoirs which are now in preparation.

Analyses for Mr. Harker. Sheet 60: *Scotland. Memoir on the Small Isles.*

Slice No.	11727.	11730.	11731.	11732.	11734.	11733.
SiO_2	46·46	49·53	49·92	50·70	71·53	44·60
TiO_2	2·07	1·76	2·04	1·89	·64	1·84
Al_2O_3	15·48	15·05	12·83	14·60	12·00	12·83
Fe_2O_3	3·63	4·49	6·96	5·23	2·90	4·65
Cr_2O_3	·02	? Tr.	Tr.	N.D.	N. Fd.	·02
V_2O_3	·05	·01	·04			·05
FeO	10·23	9·07	6·21	7·68	2·02	8·26
MnO	·48	·29	·52	·42	·36	·37
(CoNi)O	·02	·04	·03	Tr. Ni.	·02	·04
BaO	·02	·05	·09	·08	·08	N. Fd.
SrO	? Tr.	St. Tr.	Tr.	Tr.	? Tr.	? Tr.
CaO	9·05	8·08	7·25	7·20	2·33	10·95
MgO	6·80	4·25	3·78	4·15	·62	6·43
K_2O	·68	1·25	1·73	1·33	3·06	·31
Na_2O	3·01	3·93	3·72	3·71	4·27	2·59
Li_2O	? Tr.	Tr.	Tr.	? Tr.	? Tr.	? Tr.
H_2O 105°C.	·89	1·47	3·58	2·08	·13	1·33
H_2O above 105°C.	1·43	1·06	1·05	1·15	·36	·70
P_2O_5	·30	·43	·45	·49	·17	·20
S	·08	·07	? Tr.	N. Fd.	N. Fd.	·24
CO_2	Nt. Fd.	Nt. Fd.	Nt. Fd.	N. Fd.	N. Fd.	5·39
Total	100·70	100·83	100·20	100·71	100·49	100·71

r. Pollard. No other constituents looked for. (Tr., trace. ? Tr., doubtful trace. N. D., not determined. N. Fd., not found).

11727. Olivine Basalt, lava, Orval, Rum. (Anal. W. Pollard).

11730. Porphyritic Olivine Dolerite. Intrusive sill. Ealaist, Canna (Anal. W. Pollard.)

11731. Intrusive sill, intermediate in character between Dolerite and Mugearite. Eilean a' Bhaird. Canna Harbour. (Anal. W. Pollard.)

11732. Intrusive sill, intermediate between Dolerite and Mugearite, Foin-Chro, Rum. (Anal. E. G. Radley.)

11734. Porphyritic Quartz-Felsite, thick intrusive sheet, Ashval. Rum. (Anal. W. Pollard.)

11733. Tachylytic selvage of basic intrusive sheet, Kildonnan, Eigg' (Anal. W. Pollard.)

Analyses for Dr. Flett. Sheet 32 *and part of* 31: *Scotland. Memoir on Edinburgh.*

Slice No.	11863.	11864.	11867.	11859.	11860.	11865.
SiO_2	72·78	65·82	63·02	44·73	45·71	57·53
TiO_2	·19	·40	·43	1·53	1·64	·91
ZrO_2	·03	N. D.	N. D.	N. D.	N. D.	N. D.
Al_2O_3	12·86	16·37	15·50	11·89	15·23	16·47
Fe_2O_3	3·14	2·06	4·81	4·85	2·84	4·42
Cr_2O_3 }	Nt. Fd.	N. D.	N. D.	·05	·02	N. D.
V_2O_3 }				·03	·03	
FeO	·26	·18	·13	6·61	6·93	3·23
Mno	·09	·16	·10	·41	·54	·17
(CoNi)O	? Tr.	? Tr.	Tr.	·03	·02	Tr.
CaO	·92	2·74	2·67	7·69	7·34	6·16
SrO	N. D.	Nt. Fd.	Nt. Fd.	? Tr.	? Tr.	Nt. Fd.
BaO	·05	·03	Nt. Fd.	·03	·04	Nt. Fd.
MgO	·83	·51	·62	10·77	8·11	1·32
K_2O	4·14	3·48	3·96	·89	1·31	2·09
Na_2O	2·31	4·24	4·46	2·77	3·96	4·13
Li_2O	Tr.	Tr.	Tr.	? Tr.	Tr.	Tr.
H_2O 105°C.	1·05	·72	1·00	3·49	1·54	·20
H_2O above 105°C.	1·89	1·85	1·49	4·15	4·70	·82
P_2O_5	·14	·21	·16	·46	·47	·63
S	? Tr.	N. D.	·03	·05	·08	Tr.
CO_2	Nt. Fd.	1·84	1·82	Nt. Fd.	Nt. Fd.	2·47
Cl	? Tr.	N. D.	N. D.	Nt. Fd.	? Tr.	N. D.
Total	100·68	100·61	100·20	100·43	100·51	100·55

11863. Trachyte or Orthophyre (decomposed) Woodhouselea, Pentland Hills. (Anal. W. Pollard.)

11864. Trachyte, Braid Hills, Edinburgh. (Anal. W. Pollard.)

11867. Trachyte, Mortonhall, Braid Hills, Edinburgh. (Anal. W. Pollard.)

11859. Picrite, basic part of an intrusive sill at Blackburn, Bathgate. (Anal. W. Pollard.)

11860. Analcite diabase or Teschenite, less basic part of above sill. (Anal. W. Pollard.)

11865. Andesite, Blackford Hills, Edinburgh. (Anal. E. G. Radley.)

Analyses for Mr. E. B. Bailey. Sheet 33 *and part of* 41: I
Scotland. Memoir on East Lothian, etc.

Slice No.	11941.	10590.	11897.	11858.
SiO_2	44·22	46·28	47·03	46·71
TiO_2	2·70	2·06	2·64	2·40
ZrO_2	N. D.	N. D.	·03	N. D.
Al_2O_3	13·78	14·18	15·36	15·59
Fe_2O_3	5·26	3·79	3·38	8·27
Cr_2O_3	·03	N. D.	·02	N. D.
V_2O_3	·03		·03	
FeO	7·02	7·34	7·35	1·40
MnO	·40	·09	·14	·18
(CoNi)O	Tr.	·05	Tr.	Tr.
CaO	8·71	9·88	8·47	6·41
SrO	·05	N. Fd.	·05	·06
BaO	·10		·08	·08
MgO	7·51	10·82	5·10	4·90
K_2O	1·77	1·01	3·00	2·85
Na_2O	4·38	2·58	4·32	4·97
Li_2O	Tr.	? Tr.	N. Fd.	Tr.
H_2O 105°C.	·34	·31	·22	1·08
H_2O above 105°	2·83	1·66	2·60	3·16
P_2O_5	1·18	·44	·73	·76
CO_2	·37	N. Fd.	N. Fd.	1·06
S	—		·08	N. Fd.
Cl	·03		·04	N. Fd.
Total	100·71	100·49	100·67	99·88

11941. Analcite basalt, Kidlaw, Haddingtonshire. (Anal. E. G. Radley.)

10590. Olivine basalt, 1¼ mile N.N.W. of Whitekirk, Haddingtonshire. (Anal. E. G. Radley.)

11897. Teschenite, Craigleith Island, North Berwick. (Anal. W. Pollard.)

11858. Hornblende basalt. (Kulaite.) Blackie Hough, Haddingtonshire. (Anal. W. Pollard.)

IV.—PALÆONTOLOGICAL WORK.

Since the retirement of Mr. E. T. Newton, early in May, D
the palæontological department has been under the charge of Dr. F. L. Kitchin, while the vacancy caused by the promotion of Dr. Kitchin was filled in October by the appointment of Dr. Ivor Thomas.

The total number of specimens added to the palæontological collections during the year exceeded 3,600, the majority of which were obtained during the progress of the field work. The museum collection has been enriched by numerous donations, a list of which is published in the Annual Report for the year 1905. Attention may be drawn to specimens of *Belinurus*, and an example of *Palæoxyris trispiralis*, Kidston, all from the Coal Measures north-west of Ilkeston, Derbyshire,

presented by Dr. L. Moysey. Another important addition consists of a number of paratypes and special examples of ammonites from the Inferior Oolite, part of the collection of Mr. S. S. Buckman, which have been purchased.

Much time has been spent in the investigation of palæontological material collected for the purposes of current work from the Ordovician and Silurian rocks of South Wales, and from the Carboniferous of the Midland counties. This task has been partly carried out by Mr. H. A. Allen, and also by Dr. I. Thomas during the latter part of the year, but assistance has been given by specialists who are not on the staff. Thus, graptolites have been submitted to Miss E. M. R. Wood, and many of the trilobites have been examined by Mr. P. Lake. Dr. Traquair has kindly named fish remains from the Devonian, Old Red Sandstone and Carboniferous.

Considerable attention has been devoted to the revision of certain sections of the Museum collection, and a large number of specimens have been examined and renamed by specialists. The Carboniferous Lamellibranchiata have been dealt with by Dr. Wheelton Hind, and Mr. E. A. Newell Arber has revised the nomenclature of part of the Carboniferous plants. Mr. Philip Lake has continued his work on the Cambrian and Silurian trilobites, while Miss E. M. R. Wood has made further progress with her work on the graptolites. Dr. C. A. Matley completed his revision of the Cambrian and Silurian brachiopods.

Mr. H. A. Allen continued his important work of cataloguing the type and figured specimens of Jurassic Mollusca in the Museum, and has completed the section of the catalogue which comprises the Lamellibranchiata of the Oolitic rocks: this is published as an appendix on pp. 175–195. Increased attention has been paid to the registration of specimens in the Museum, and in the limited time available for this purpose Mr. S. W. Morgan has made good progress.

Mr. J. Pringle was engaged during eight months of the year in collecting fossils, principally from the older palæozoic rocks of South Wales. Among the specimens obtained from Upper Arenig rocks at a locality in the neighourhood of St. Clears, Mr. P. Lake recognised an example of the genus *Sao*. This occurrence is of great interest, and a further search is to be made at the same locality in the hope that additional material may be obtained for the purpose of study.

During a visit to Mansfield Colliery, Nottinghamshire, Mr. Walcot Gibson detected the presence of a marine fauna in the Middle Coal Measures passed through at a depth of 317–333 yards, in No. 1 Shaft (see p. 21). Mr. Gibson made a collection from the material brought to the surface in the course of sinking, and an examination of the fauna proves the presence of a marine band characterised by an assemblage of forms which is very reminiscent of that found below the Gin Mine Coal at the Nettle Bank and Speedwell Collieries in North Staffordshire.

The following are the principal forms obtained, which have been determined for the most part by Dr. Ivor Thomas :—

Spirorbis ?
Chonetes laguessiana, *de Kon.*
Lingula mytiloides, *J. Sow.*
Productus (spines).
Ctenodonta lævirostrum, *Portl.* sp.
Myalina cf. compressa, *Hind*
Nucula gibbosa, *Flem.*
Nuculana attenuata, *Flem.* sp.
Posidoniella lævis, *Brown* sp.
„ sulcata, *Hind*
Pseudamusium fibrillosum, *Salt.* sp.
Pterinopecten carbonarius, *Hind*
„ papyraceus, *J. Sow.* sp.
Euphemus cf. Urei, *Flem.* sp.
Loxonema ?
Glyphioceras bilingue ? *Salt.* sp.
„ Phillipsi ? *Foord and Crick*
„ sp.
Orthoceras cf. asciculare, *Brown*
„ sp.
Pleuronautilus sp.
Cytherella sp.
Acanthodes sp.
Cœlacanthus elegans, *Newb.*
Elonichthys Egertoni, *Egert.* sp.
Listracanthus Wardi, *A. S. Woodw.*
Pleuroplax Rankinei, *Hanc. and Atth.* sp.
Rhizodopsis sauroides, *Will.* sp.

There are also single examples of *Nucula*, *Allorisma*, and *Pterinopecten* which are considered by Dr. Wheelton Hind to represent new species. In addition, a radially-ribbed shell, showing peculiar surface sculpture, has been provisionally referred to *Spiriferina*. It is represented by one specimen in an unfortunately imperfect state of preservation, but if correctly assigned to this genus, there can be no doubt that it belongs to some undescribed species.

Glyphioceras bilingue is a characteristic form of the Pendleside Series, and if the specimens from Mansfield doubtfully referred to this species should prove to be truly referable to it, such an occurrence will be of great interest. It may be noted that one of the forms found in the marine band below the Gin Mine Coal at Nettle Bank, in North Staffordshire, has been recorded by Mr. J. T. Stobbs as *Glyphioceras bilingue ?*

A great majority of these species found at Mansfield occur also in the fauna of the marine band below the Gin Mine Coal in North Staffordshire, and the appearance of similarity to that fauna is further strengthened by the comparative richness and diversity of the Mansfield assemblage. It should be remembered, however, that most of the above-named species have a somewhat extensive vertical range, and that distinctive elements which alone would warrant a correlation are but too scantily present. At the same time, it must be conceded that the comparative abundance of *Posidoniella sulcata* in the marine band below the Gin Mine Coal, together with the fact that *Listracanthus Wardi* is only known from that horizon (at Nettle Bank), strongly suggests a correlation between the Gin Mine and Mansfield marine bands.

From No. 2 Shaft, Mansfield Colliery, Mr. Gibson obtained *Anthracomya modiolaris*, J. de C. Sow. sp., *Carbonicola aquilina*, J. de C. Sow. sp. and *Naiadites modiolaris*, J. de C. Sow. sp., which occur in a band above the Dunsil Coal, at a depth of 19½ yards below the Top Hard Coal.

In October, Mr. H. A. Allen, accompanied by Mr. W. Whitaker, paid a visit to the Northern Outfall Sewer-works at Barking, in order to obtain information afforded by the sections before the work was closed down. Two conduits for sewage are under construction, and these are supported upon transverse arches the piers of which are carried down to a suitable foundation in the River Drift. By the kind permission of Mr. H. G. Lloyd, the Resident Engineer, a section at pier 309 was examined and the following beds were seen:

[Soil and made ground removed.]

Alluvium	Blue Clay	4 feet
	Peat (with tree-trunks)	15 „
River Drift, Sand and Gravel.		

The bed of peat, with tree-trunks, is of unusual thickness at this point. Some of the trunks were nearly a foot in diameter and could be cut like cheese. A few logs resembled Yew, but the structure of the wood was not sufficiently distinct for determination.

From a cave in the Carboniferous Limestone near the base of a cliff at East Clevedon, Somerset, Dr. H. C. Male brought a large series of bones to the Museum for determination. The bones thus far examined by Mr. Allen comprise:

Ursus spelæus, Rosenm., mandibles with teeth, vertebræ and limb-bones; also some lumbar vertebræ which had been injured or subject to some rheumatic affection, anchylosed, and then excavated by disease.

Equus caballus, Linn., fragments of skull, teeth, and limb-bones.

Canis lupus, Linn., mandibles with teeth,and limb-bones.

„ *vulpes*, Linn., right mandible with teeth.

Microtus, a series of jaws and limb-bones, among which Mr. E. T. Newton recognises *M. amphibius*, Schrank, *M. agrestis?* Lataste, *M. gregalis?* Woldrich, and *M. ratticeps*, Keyserl.

A large number of gasteropods (*Hygromia hispida*, Linn., and *Succinea elegans*, Risso) were found in the talus.

The following specimens in the Museum have been figured during the year:—

In the Palæontographical Society's Volume for the Year 1905.

Fauna of the Cornbrash, Part I.

By the Rev. J. F. Blake, M.A.

Alaria composita, *J. de C. Sow.* sp., pl. vii., fig. 7, p. 64.
Bittium pingue, *sp. n.*, pl. vii., fig. 10, p. 67.
Cylindrites Thorenti, *Buv.* sp., pl. ix., fig. 5, p. 98.
Eucyclus armiger, *Lycett* sp., pl. viii., fig. 10, p. 84.
Hydatina limitata, *sp. n.*, pl. ix., fig. 8, p. 100.
Littorina cassius, *d'Orb.* sp., pl. viii., fig. 11, p. 85.

Natica montreuilensis, *Héb.* and *Desl.*, pl. viii., fig. 5, p. 80.
Pleurotomaria buchiana, *d'Orb.* sp., pl. viii., fig. 23, p. 93.
Purpurina ? condensata, *Desl.*, pl. viii., fig. 13, p. 86.
Clydoniceras Hochstetteri, *Oppel* sp., pl. vi., fig. 2, p. 55.
Macrocephalites Herveyi, *J. Sow.* sp., pl. iii., fig. 7, pl. iv., fig. 2, p. 46.
,, macrocephalus, *Schloth.* sp., pl. iii., fig. 4, p. 43.
,, typicus, *nom. nov.*, pl. iii., fig. 3, p. 42.
Perisphinctes subbakeriæ, *d'Orb.* sp., pl. v, fig. 2, p. 49.

Cretaceous Lamellibranchia, Vol. II., Part 2.

By Mr. H. Woods, M.A.

Gervillia rostrata, *J. de C. Sow.* sp., pl. xi., figs. 13, 22, p. 83.
Perna ricordeana, *d'Orb.*, (text-figure), p. 83.
Pteria (Oxytoma) tenuicostata, *Roemer* sp., pl. viii., figs. 19, 20, p. 61.
,, (,,) *sp.*, pl. viii., fig. 15, p. 60.
,, (Pseudoptera) gaultina, *sp. n.*, p. ix., fig. 11, p. 67.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOL. LXI.

By Miss J. Donald.

Loxonema Grindrodii, *sp. n.*, pl. xxxvii., fig. 1, p. 566.

By Dr. Wheelton Hind, B.S., F.R.C.S.

Nucula oblonga, *M'Coy*, pl. xxxv., fig. 21, 21*a*, p. 536.

V.—MUSEUM OF PRACTICAL GEOLOGY.

Mr. Howe

Slight progress has been made with the task of preparing material for an exhibit of British clays and a series of specimens has been collected and photographs have been taken to illustrate the china clay and china stone industry of Cornwall.

The series of road-making stones, tested in the attrition machine by Mr. Lovegrove, engineer to the Hornsey Borough Council, has been arranged and catalogued. The results of a numbers of tests, together with a brief petrological description, prepared by Dr. Flett in the petrological department, have been published in the "Surveyor" and "County Council Times"; and will be re-issued shortly in book form.

This account of the roadstones does not profess to be exhaustive; in the short time that has elapsed since its publication, over 50 additional specimens have been received. The illustrations, prepared from photographs taken in the Survey and Museum photographic laboratory by Mr. Hall, included 74 photomicrographs of the stones; these should prove useful, not only to the professional men for whom they were designed, but they may also be serviceable to teachers and students of geology.

The following extract from the "Surveyor" (December 10th, 1905, page 770–775) is reproduced by the kind permission of the Editor, Mr. Gibson Thompson; it follows the detailed petrological description of the stones and enumerates the

Mr. Howe. general conclusions arrived at, as the result of the analysis of Mr. Lovegrove's Series of Tests, viewed in the light of petrological characteristics.

Road Stones.

(See Plates I., II. and III. at the end of this Volume.)

DISCUSSION OF THE RESULTS.

In the foregoing brief notes each stone has been described separately. An attempt will now be made to summarise what appear to be the salient features of structure and mineral composition in each petrological group, and to show, if possible, the bearing of these characters upon the behaviour of the stones in the testing machine.

GRANITE GROUP.

The average attrition result from thirteen tests in this group is ten; but it is fairly easily divisible into smaller petrological sub-groups, and if the averages for these are taken separately more light is thrown upon their relative values; thus, five granite tests yield an average of 11·05, three gabbros give 10·06, three diorites 9·04, two hornblende gneisses 8·31.

From these figures one might be disposed to infer that the hornblende gneisses were the best resisters of the attrition action, the diorites next, and so on; but, as a matter of fact, the number of tests confined to a single type is still far to small to permit of generalisations of this kind; moreover, the numerical differences themselves are often unimportant, for they lie within the limits of experimental error.

In an examination of the bearing of the petrological characters upon the attrition results in this group three prominent factors stand out. They are: (1) Texture, (2) the kind of mineral, (3) the state of freshness of the minerals. With regard to the first of these, it is evident that fineness and evenness of grain is an advantage, and that coarse grain or porphyritic structure is disadvantageous. It is on account of the *granitic texture* that the rocks of this group, taken as a whole, are not higher in the attrition scale.

The influence of the kind of mineral (2) is not so easy to determine, but, other things being equal, a high proportion of hornblende appears to be favourable to resistance; quartz in a like manner is favourable because of its hardness and lack of cleavage.

Fresh unaltered original minerals are not absolutely essential to a high capacity to resist abrasion; the two stones that take the best position in the test scale for this group are considerably altered—the felspars are decomposed, and their substance is a mixture of smaller mineral units; the ferro-magnesian minerals have changed to chlorite and to fibrous uralitic hornblende.

Alteration of the minerals in the rocks of this group appears to have a toughening effect, which is probably due to reduction

in the size of the component grains, together with a greater felting and interdigitating of the crystals. A very important feature in the best rocks is the late crystallisation of quartz or the production of secondary quartz in a kind of ground-mass, which seems to bind the whole together with a hard, resistant material. Mr. Howe.

It is possible for fresh felspar to behave fairly well in the test when the grains or crystals are small and are closely matted together.

PORPHYRIES AND PORPHYRITES.

The stones that fall into this petrological group take a higher place in the attrition tests than those in any of the other groups. This seems to be due to the regular distribution of quartz throughout the ground-mass of the rock, associated with felspar, either in a microgranitic or in a micropegmatitic structure. The ferro-magnesian minerals occupy a quite subordinate place in these rocks.

When the test results of these rocks are compared with those of the granites, which consist of the same minerals, but in larger grains, their superiority is manifest. It is an excellent example of the importance of rock structure. The fine-grained ground-mass, or matrix, in which the larger crystals lie, consists of quartz and felspar, usually imperfectly crystallised, forming a dense "felsitic" aggregate. Hence there are no natural cleavages or planes of weakness within the rock which will open up and allow the stone to crumble.

It is not at all necessary that the felspar should be fresh; in the best stones it is cloudy, altered, and often stained by iron oxides.

A small amount of decomposition, by the production of additional quartz, which acts as a cementing material, and of fibrous scaly muscovite, which resembles a feltwork, instead of being disadvantageous may operate in a contrary way, improving the toughness and durability of the stone.

BASALT, DIABASE AND DOLERITE GROUP.

Considerable difficulty is experienced when an attempt is made to correlate petrological facts with the test results in this complex group of rocks. This is due in part to the impossibility of sharply defining petrological species; border-line varieties occur which embrace the characters of more than one rock type. For instance, certain diabases from North Wales are extremely variable within moderate limits, and approach the porphyrites. These rocks of the porphyrite type seem capable of resisting the attrition action with pre-eminent success; this appears to be due to the fine grain and regular size of the mineral constituents, and more particularly to the micropegmatitic arrangement of the quartz and felspar throughout the ground-mass. The precise influence of the enstatite, which is largely altered

Mr. Howe. to bastite, cannot yet be ascertained. Although these rocks resemble porphyrites, their mineral composition has led to their being placed by many petrologists among the (quartz) diabases.

Among the more typical members of this group the ophitic structure is no doubt a factor of importance; it appears that stones with smaller augite units are better than those with larger ones, and as a general rule the coarser-grained stones take a lower place than the finer ones.

With regard to alteration of the minerals, it is important to distinguish between two kinds. If the original augite has been altered to chlorite and calcite, the result is usually a poor rock; but if the alteration product is fibrous uralite, the result seems to be even better than with fresh augite. Other things being equal, the decomposition of felspars does not produce adverse results; but this depends entirely upon the nature of the alteration products—epidote, albite, quartz and mica are not bad, while calcite and kaolin generally produce a weak stone.

The *rôle* of olivine as regards the attrition test is not clear; it is found in one of the best rocks of the group in a very fresh condition, and in some of the worst rocks in a highly-altered condition. The probability is that in all cases it is a source of weakness in the stone. Much depends on its abundance of freshness; if it has passed into serpentine, chlorite, limonite, and carbonates it is disadvantageous, at least if it occurs in numerous large units.

ANDESITES.

Among the andesites, fine grain, with complete felting of the felspar laths, produce the most resistant stone. A fluxional arrangement of the felspar laths, whereby they are given a uniform orientation, is inferior to the felted structure in wearing capacity. Markedly porphyritic structure is a detrimental quality. This group of rocks is large and diverse; its members consist very largely of felsar, and hence, unless the crystals of the ground-mass are small and well felted together, the attrition tests are only moderately good. The absence of quartz has an important effect in diminishing the hardness (of porphyrites). If calcite and limonite abound in the rock as alteration products it cannot yield good results.

HORNFELS.

Too few of the rocks of this group have been tested to make the results generally applicable. Their structures and minerals vary so greatly that the few tests included in the table are quite insufficient to show what place the group would hold as road-stones. On the whole it is clear that the hornfelses are above the average. The heating which they have undergone has driven out part of their water of composition and re-crystallised many of their minerals; hence the grains are usually fresh and

comparatively hard. But hornfelses are well known to be rather brittle, probably a consequence of their evenly granular texture. It is interesting to compare Nos. 127 and 130, two weathered diabases, with No. 128, a granular hornfels formed by heating a similar rock. The hornfels is the freshest of the three, but it is evidently rather more brittle; all three rocks, however, are excellent. Apart from the structure, hornblende seems preferable to biotite as an important ingredient. Mr. Howe.

QUARTZITES AND SANDSTONES.

These two types of stone have been classed together on account of their similarity of composition and the impossibility of sharply delimiting one from the other. Notwithstanding this, a glance at the attrition tests makes it evident that the quartzites constitute a class by themselves; they are all gathered at the head of the list, and their average attrition result is 5·5, the average of the remaining sandstones is 18.

The superiority of the quartzites over other members of the group lies in the complete cementation of the grains by quartz, the same material as the bulk of the grains themselves; the result is an intensely hard, fairly homogeneous body, free from pores. The size of the grain appears to be a factor of quite subordinate importance in quartzites and sandstones. Of the three sandstones that approach nearest to the quartzites in the attrition tests, two are very fine-grained, even-textured and thoroughly-compacted stones, with an abundant supply of microscopic mica and chlorite flakes forming a felted mass among the tiny quartz grains; the third sandstone is much more uneven in grain, and the grains vary in their nature, but there is a large amount of fine siliceous cementing matrix, and the stone is thereby rendered compact.

The pre-Silurian and Silurian sandstones are better than the Carboniferous ones among those tested, but from our knowledge of the microstructure of samples not included here we can say that this is not a rule of universal application.

Generally speaking, unless there is a good siliceous matrix all varieties of sandstone fail in the tests, whether their constituent grains are large or small and whether they are heterogeneous or similar in kind.

LIMESTONE.

The low position occupied by the limestones in the test series is readily accounted for by their greater softness as compared with the other stones. The dolomites, magnesian limestones, and pure limestones have been classed together for our present purpose, because the passages from one to the other are so gradual.

Mr. Howe. If we take the pure dolomites alone, it is clear that those behave best in the attrition test which have a fine-grained, even granular texture, with irregular-shaped grain interlocking closely one with another and with a general absence of porous cavities. A dolomite is by no means always better than a limestone, but the best type of dolomite will be more resistant than the best limestones, being harder.

Among the limestones, those stand highest that are composed of a mixed assemblage of small organic remains, notably of foraminifera, and possess at the same time a somewhat bituminous composition (this characteristic is often associated with foraminifera in carboniferous limestone). Crinoidal limestones do not stand so high, evidently on account of the ready cleavage of the particles of calcite, which is not only a soft mineral but has an extremely perfect cleavage, hence it wears rapidly and crumbles easily under repeated small blows; but if the crinoid fragments are small and uniform in size, set in a matrix of fine calcareous matter, the stone may compare well with other limestones.

FLINTS.

With rocks that possess such uniformity of structure and of chemical composition as the flints, the utility of a microscopic examination of thin slices ceases to exist. In other words, we are at present quite unable to point to any differences of texture or structure in the flints that appear to be connected in any way with the behaviour of different samples of these stones in the testing machine. It is quite possible that after testing and slicing a great number of samples some hitherto unobserved microscopic character might be detected which would explain the differences of behaviour; no such character has yet been noticed.

On looking over the samples of tested flints no essential differences of angularity, colour, or form can be seen; perhaps the presence of more or less quarry water may account for something. It is important to bear in mind the fact that "surface" flints, just as well as "pit" flints, may contain quarry water. It is usually regarded as an established fact that "surface" flints are superior to "pit" flints for road purposes; so far as attrition goes, this is not supported by the test results, and the explanation of this divergence from the accumulated experience of many surveyors is probably this: Many of the consignments of "surface" flints do not really possess the best properties of the "surface" variety although they are certainly not "pit" flints. The weathering of a flint, whereby a good "surface" flint is produced, consists in the removal of its quarry water, the removal of some of the soluble colloid silica from between the minute microlites of crystallised silica, and to some extent to the introduction of more of the

latter substance into the minute interstices in the form of a cement. If these changes have not taken place in the stone it is immaterial whether it is styled "surface" or "pit" flint. The presence of quarry water in a stone rendered slightly porous will tend to weaken its resistance to repeated blows (*vide* porosity). Mr. Howe.

Once the sharp edges of the flint are worn away, its natural hardness causes it to take a very high place in the attrition tests, but to this rounded condition of the stone there are objections in practice with which we are not here concerned.

VALUATION OF THE NUMERICAL RESULTS.

Too much reliance must not be placed upon the exact numerical value of the test results; from the nature of the case *absolute* measurements are impossible. Some of the results cannot be immediately explained on petrological grounds. The reasons for this are numerous: some of them may be mentioned here. The *number and size* of the individual stones in a test batch, although kept as nearly regular as possible, may yet vary sufficiently to cause some difference. The *angularity* or *roundness* of the stones is a factor which certainly influences the result; rounded stones wear more slowly, as was pointed out by Daubree. This fact is very clearly brought out in the duplicate flint tests (see table of attrition tests). The *temperature* at which the test is made may have a sufficiently wide range of variation to produce slight differences in the tests. *Quarry variations* are perhaps the most important; from the same quarry the quality of the stone undoubtedly varies from time to time, and it is quite unlikely that a test from a certain quarry repeated, say, two years hence would give identical results. The stone also varies from bed to bed, often both horizontally and vertically; or the variation may occur rapidly and irregularly from spot to spot in the case of many apparently homogeneous masses of igneous rocks.

But in spite of several apparently anomalous results the general reliability of the tests is amply confirmed by the petrological examination of the stones, and this is emphasised by the fact that so many highly favoured stones occupy prominent places in the list.

The following diagram, Plate I., will serve perhaps better than words to show the relative position of the different groups of stone when arranged according to their powers of resistance to the action of the attrition testing machine. In each case the ten highest results are taken for each group, except where a smaller number were actually tested.

Mr. Howe. Stated in another way, the results stand thus:—

Petrological Groups.	Number of stones tested.	Attrition Results.		
		Highest.	Lowest.	Mean (approx).
Quartz—Diabases	4	2·66	5·47	3·82
Diabases, Dolerites and Basalts	21	3·42	29·93	12·73
Porphyries and Porphyrites	14	3·71	13·50	6·7
Granitic Group	13	6·61	15·23	10
Granite	5	6·61	15·23	11
Diorite	3	7·49	9·94	9
Gabbro	3	9·08	10·74	10
Gneiss	2	8·03	8·59	8
Andesites	4	5·98	15·68	10
Hornfels	4	6·47	8·05	7·5
Sandstones and Quartzites	23	3·73	44·99	15
Quartzites	5	3·73	7·30	5·5
Flints	11	7·49	13·38	10
Pit Flints	5	7·81	10·62	9
Surface Flints	6	7·49	13·38	10·5
Limestones	11	11·13	33·89	20

General Conclusion.

Enough has been said to show that each type of rock must be judged by its own criteria; the classification of the roadstones in Plate I. does not imply that only those should be laid down that are represented by the higher curves, and each stone—even the frequently maligned limestone—has its place in road economy. But the attrition tests, enforced by a knowledge of the mineral composition and structure of the stone, indicate most clearly what are the best varieties of stone in each group.

It is still premature to attempt to draw any sweeping conclusions; before this can be done more stones must be tested and examined from some of the groups that are as yet only poorly represented. There are, however, one or two points which are worthy of attention. It is well known that the hardness and toughness of a stone depend upon the hardness and toughness of the mineral constituents, and upon their mutual relationships. The hardest and toughest stones combine *abundance of a hard mineral*—*e.g.*, quartz—with a *dense fine-grained texture*.

The best rock structures for wear are the micropegmatitic (or micrographic), the micrograniticc, and the ophitic. In the last-mentioned structure a framework of augite binds together the felspar crystals, and the smaller the augite units the better the result. The two other structures are similar in this respect—that they present a fine-grained mixture of quartz and felspar intimately related and bound together into a dense hard mass.

POROSITY.

Whatever is conducive to porosity is disadvantageous, whether it be the absence of cementing substance between the grains or a tendency in one of the mineral constituents to cleave. This influence of porosity in producing low attrition results may be seen in comparing the "wet" with the "dry" tests. With few exceptions, the "wet" tests yield the higher values of dust. The exceptions are mostly flints and quartzites—*i.e.*, rocks which are not porous. The difference is greatest in porous rocks (sandstone), rocks with minerals that have a good cleavage (limestone, dolomite, granite); rocks with soft minerals easily split open (diabases, weathered basalts), rocks with a variety of minerals (granite, diabases). These facts point to the action of the incompressible water exerting a disruptive pressure within the crevices with every blow and shock. The bearing of this point upon the waterproofing of porous stones might be borne in mind. Mr. Howe.

FRESH AND ALTERED ROCKS.

There is much confusion among practical men unacquainted with petrology, arising from an improper conception of the meaning of the terms "fresh," "altered," "decomposed," as they are applied to rocks or the minerals composing them.

If we use the terms "fresh" and "decomposed" = rotten, we in general convey the ideas of goodness and badness respectively; this is not the case when reference is made to rocks. When we speak of a mineral being in a fresh condition we mean that it possesses its inherent properties in an unimpaired state; if the original or primary minerals are not altered by subsequent processes they are said to be "fresh." A fresh *rock* is one in which the minerals that compose it are fresh. When a mineral within a rock alters or is decomposed as the result of certain forces acting upon it, it breaks up usually into one or more *new minerals*, each one in its own way being as "fresh" as the original mineral.

It is possible for the alteration of a rock to make it actually stronger than before. Some of the new minerals produced by alteration (molecular rearrangement) may be an improvement upon the original; others may be the reverse. When a rock is acted upon by surface weathering agents it frequently happens that certain selected minerals substances are removed, and it is thereby weakened, or softer minerals are introduced.

For this reason it has been suggested that the term "decomposition" should be confined to surface weathering, while alteration is maintained for more deep-seated molecular rearrangement within the rock; but the suggestion is not regularly acted upon.

The microscopic examination of the rock shows what the action of the alteration is, and whether it is likely to be beneficial or not in its effects; thus the alteration of augite to

Mr. Howe. chlorite produces a result that is usually inferior to the original in wearing properties, while the alteration to uralite appears to be superior.

The very best rocks in these tests are altered rocks, and as a general rule a certain amount of alteration of the felspars seems to be an advantage. The reason for this is that the alteration produces a *number* of mineral units where formerly only *one* existed; in other words, the texture is made finer and often the interlocking of the grains is made more complete. A large fresh crystal of felspar, by its rigidity and perfection of cleavage is less able to resist impact than the same volume of substance in the condition of an intimate mixture of granules of mica, sericite, kaolin, or epidote, especially if they are united by a quartzose cement, as is frequently the case.

In short, alteration by reducing the size of the grains and felting them more closely tends to enhance the *toughness* of the stone. It is only when large quantities of soft minerals are introduced, or some ingredient is removed, usually by surface agencies, that alteration is liable to be inimical to the wearing properties.

Fineness of grain makes for toughness in all classes of stone. A stone made of heterogeneous particles or minerals will wear better in a fine-grained condition than when coarse, but if the grains are somewhat large, provided they are fairly uniform in size and held together by a fine matrix, the stone may wear as well as a finer-grained one.

Great care has been taken in the foregoing notes to avoid complicating the present issue by references to any of the stones in road practice. We have set ourselves to examine what light could be thrown upon the attrition tests by the microscopic examination of the stones. Notwithstanding certain evident imperfections, we are satisfied as to the practical utility of combining these two testing instruments, and we believe that, after working carefully through the series of stones with the microscope, it is possible to forecast the behaviour of a new stone from the thin section, with very fair accuracy.

II.—SCOTLAND.

I.—FIELD WORK.

The ground surveyed in the Highlands was arranged in two districts as follows:— Dr. Horne

1. West Highland district, embracing Knapdale and the area between Glencoe and Ben Nevis and unfinished tracts south of Glencoe, under Mr. Clough, M.A.
2. North Highland district, including parts of the counties of Inverness, Ross and Caithness, under Dr. Peach, F.R.S., and after his retirement Mr. L. W. Hinxman, B.A.

The Carboniferous areas were arranged in two districts:—

3. Glasgow district, comprising areas between Paisley and Cathcart and between Glasgow and Cumbernauld, under Mr. L. W. Hinxman, B.A., after the retirement of Dr. Peach.
4. Airdrie district, including parts of the Campsie and Kilpatrick Hills and Charlestown, under Mr. Clough, M.A.

In the West Highland District, field-work was carried on in the deer forest areas north and south of Glencoe (Sheet 53) and in the autumn it was continued in the low ground of Knapdale (Sheet 28). The memoir on The Geology of Mid Argyll (Sheet 37) was published and the sheet memoirs of 45 (Oban and Dalmally) and of 36 (Crinan, Kilmelfort, and the Isles of the Sea) have been proceeded with.

In the North Highland district, further progress was made with the mapping of the deer forest areas in the neighbourhood of Loch Monar and the valley of the Meig (Sheet 82), and thereafter field-work was continued in the tract extending from the basin of the Findhorn to Carrbridge and the river Dulnan in Sheet 74. In the autumn a considerable area occupied by Old Red Sandstone strata in the north eastern part of Caithness was mapped. The memoir descriptive of the geology of the country round Blair Atholl, Pitlochry and Aberfeldy has been published. The memoir of Sheet 71 (Sleat, Balmacarra, and Glenelg) is in an advanced state of preparation, and those of Sheets 83 (Beauly and Dingwall) and 93 (Central Ross-shire, Garve, Ben Wyvis and Fearn) have been proceeded with.

After the close of the Highland season the revision of the Carboniferous areas in the western part of the midland valley was undertaken with the view of completing the tract included in the proposed Glasgow district map. By the end of the year considerable progress was made with the work. The re-examination of the Carboniferous areas in East Lothian, Midlothian, and that part of West Lothian extending westwards to Bo'ness and Bathgate has been finished, and the memoirs descriptive of the geology of Sheets 32 and 33 are now in progress.

Mr. Horne. The memoir on the Oil-Shale Industry of the Lothians, with special sections relating to the geology of the Shalefields, the methods of mining, the Chemistry of the oil-shales, and the products of manufacture, has been completed.

I.—West Highland District.—Glencoe, Glen Etive, Glen Leven, and Knapdale, Argyllshire.

Mr. C. T. Clough, M.A., District Geologist.
Mr. J. S. Grant Wilson, Mr. H. B. Muff, B.A., Mr. E. B. Bailey, B.A., Mr. G. W. Grabham, M.A. — Geologists.

Mr. Clough. Mr. Clough was unable to take part in the mapping of this district owing to memoir work which occupied his time in the office during the Highland season. For a similar reason Mr. Wilson's field-work was confined to the Knapdale area.

In the Glencoe region, the large fault—which may be termed the Glencoe fault—previously described by Mr. Muff as bounding the volcanic series on the west*, has now been followed by Mr. Bailey for a considerable distance in the area draining into Loch Leven. His work strongly suggested that the original inequality of the surface on which the volcanic rocks were laid down was less than had been previously supposed, and that the most marked changes of level were due to faults. The area on Beinn Caitlein, referred to in last year's Summary, was accordingly re-examined, and, though the evidence is not clear, it now seems probable that the basement breccias near the top of the hill are separated from the basement breccias found near the bottom of Glen Etive, near Dalness, by an obscure crush line striking W.N.W., which is probably a branch of the "flinty crush" described last year. There is not much doubt that this crush line joins the Glencoe fault, and as the latter has now been shown by Mr. Bailey to twist again into an E.S.E. direction, its course from Beinn Ceitlein by Allt Fhaolain and Loch Triochatan to Altnafeadh must roughly describe the north western half of an ellipse, the longer axis of which strikes W.N.W.. This fault has not been traced eastwards beyond Beinn Ceitlein and Altnafeadh, probably owing to later igneous intrusions. The large masses of volcanic rock are all found in the central area of depression within the circular fault.

The survey of that part of Knapdale which lies between Loch Sween and Loch Caolisport is now completed, and it is clear that the phyllites east of the pebbly quartzite of Kilmory Bay, which form a large part of the area surveyed in 1904, between Achahoish and Ellary, belong to the Ardrishaig phyllite series. The pebbly quartzite referred to is part of the Loch Awe quartzite, and within the Ardrishaig phyllite series there is at

* See Summary of Progress for 1904, p. 67.

least one bed of calcareous conglomerate * which differs in character from the pebbly band at the base of this quartzite. Mr. Clough

The regions of Glencoe and Knapdale are far apart and differ in many points, but it has now been shown that in each there is a great zone of quartzite near the base of the Ardrishaig phyllite series. The zone is also well developed on parts of Loch-Fyne-side, where it was mapped by Mr. Hill many years ago.†

HIGHLAND METAMORPHIC ROCKS.

Glencoe, Glen Etive, and Glen Leven.

Glencoe and Dalness Area (Glen Etive).—In completing the mapping of the schists between the northern margin of the Cruachan granite and the boundary fault of the Lower Old Red volcanic series, the belts of schist were found to occur in the order given by Mr. Clough on page 65 of last year's Summary of Progress. The structure of the district is evidently that of a huge overfold, the limbs of which dip gently westwards and are at least three miles in length (from trough to crest). The quartzite which caps the hills, also forms the floors of the glens. On its margins is found a parallel-banded series consisting of alternations of quartzite and mica-schist. It must be noted that the calc-silicate hornfels, which succeeds to the parallel banded series on ascending from the floors of the glens, is absent, or but poorly represented, below the quartzite capping of the hill tops. The mica schist and garnetiferous mica schist which appear to be very thick on the middle slopes of the hills, are proved to be continuous with the Ardrishaig phyllites of Glen Creran and Glencoe. The succession in Glen Etive may, therefore, be connected with the succession in the Glen Creran and Loch Leven area given by Mr. Wilson on p. 63 of last year's Summary of Progress. The mica schist and garnetiferous mica schist being part of the Ardrishaig phyllite series, the Glen Etive calc-silicate rock must lie at the base of the Ardrishaig phyllites and be followed in downward succession by the parallel banded series and white quartzite. The white quartzite of Glencoe and Glen Etive is, therefore, the lowest belt hitherto recognised in the district. It clearly occupies a different horizon from the pebbly Schichallion quartzite of the Glen Creran area, and may conveniently be called the Glencoe quartzite. Mr. Muff.

Much of the area mapped lies within the aureole of contact metamorphism of the Ben Cruachan granite, and contact alteration is appreciable in the phyllites at a distance of one mile from the edge of the granite outcrop.

Southern side of the River Leven.—The district north of the Glencoe lavas is chiefly occupied by the Glencoe quartzite with several infolds of the Ardrishaig phyllites. The strike is north west in the western portions of the area, but changes to north in the central parts, and thence to north-east in the eastern. Mr. Bailey

* Summary of Progress for 1904, pp. 66 and 67.

† Geological Survey one-inch map 37.

Mr. Bailey. Metamorphism increases rapidly from west to east, and at the eastern margin, just before reaching the granite of the Moor of Rannoch, a band of garnetiferous mica schist, which has been followed for some miles, may possibly represent the Ardrishaig phyllites in a highly altered condition.

Mr. Grabham. *Buchaille Etive Mòr.*—North of Stob Dearg some flaggy impure quartzose beds crop out from beneath the volcanic rocks. They agree in character with those noted by Mr. Kynaston towards the south *, being generally banded and usually presenting various shades of colour, sometimes pink, possibly owing to the presence of felspar.

KNAPDALE, BETWEEN THE SOUND OF JURA AND LOCH FYNE.

Mr. Bailey. *Cruach Lusach Area.*—In this area, extending between Eas Daltot and Kilmichael and south eastward to a part of the public road near Loch Errol, the following groups of rocks of sedimentary origin have been mapped:—

Loch Awe quartzite series.
Easdale slate series.
Ardrishaig phyllite series.

The first mentioned series is divisible into two zones, the Ardnoe beds above and the pebbly quartzite below, as described in previous Summaries. In some places the pebbly basement beds come in contact with the Easdale slates, as is general further north and west, and in others with the Ardrishaig phyllites. Sections showing these different relations are seen along folds which approach to within half a mile of one another. A very gradual overlap of the Loch Awe quartzite series on to different members of the Ardrishaig phyllite series has also been observed. Where the former series comes in contact with the Easdale slates at Loch nam Ban, we find at its base a bed of dark grey limestone abundantly charged with large pebbles of quartz and felspar. Above this comes a porphyritic epidiorite which resembles a deformed pillowy lava in which the interspaces between the pillows have been infilled with sediment. It is, therefore, probable that this epidiorite represents a lava contemporaneous with the basement beds of the Loch Awe quartzite. Dr. Peach has already described † volcanic rocks on the western side of Loch Sween, occurring in the Easdale slate group, and if these facts can be taken to indicate that volcanic conditions continued from the one group into the other, then it seems to follow that the overlap at the base of the Loch Awe quartzite series does not here represent a great break in time. Again, for a little distance above the base of this quartzite series, beds of pebbly limestone and of black slate are intercalated with pebbly quartzite, and with them is a bed of dark grey limestone, about an inch thick, which is indistinguishable from beds in the underlying

* Summary of Progress, for 1900, p. 36.
† Summary of Progress, for 1903, p. 69.

slates. In those places where the Loch Awe quartzite series comes in contact with the Ardrishaig phyllites, neither the lava-like rock, nor the pebbly limestones are found. Mr. Bailey.

The Ardrishaig phyllites are unfortunately not exposed in the core of the fold in which the Easdale slates occur, but it is not probable that any great thickness of intermediate beds is hidden by the overlap of the quartzite. The following zones have been established for the remaining visible portion of the Ardrishaig phyllite series:

Upper Calcareous zone.
Phyllite with quartzite bands and at least one bed of sandy limestone with pebbles.
Homogeneous dark green phyllites, free from intercalations of quartzite.
Phyllites with bands of quartzite.
Lower Calcareous Zone.
Thick zone with a large proportion of quartzite.

It is probable that the upper calcareous zone represents in part at least the Appin limestone. Unfortunately, it is associated with a coarse epidiorite sill, whereby it has been hornfelsed to such an extent that the original nature of some of its members is rendered doubtful. Certain greenish bands in the limestones are very rich in tremolite and must represent dolomitic bands.

The quartzite beds of the Ardrishaig phyllite series are always of a uniform fine-grained type, very different from that of the Loch Awe quartzite.

The lower calcareous zone is well seen in the neighbourhood of Loch Errol, where a thick band of limestone has been traced for some distance.

Area between Castle Sween and Eas Daltot.—The boulder bed of Port Ban (*Summary of Progress* for 1904, p. 67), which forms the basal portion of the Loch Awe quartzite series, has been found at various points on the west side of the Abhainn Mhor. In the deep ravine excavated by this stream a short distance above the bridge on the public road from Achahoish to Kilmory, there is a fine exposure of this bed resting directly upon the Ardrishaig phyllites, which occupy the lower portion of the Abhainn Mhor valley. As this boulder bed is traced north-east to Eas Daltot, it gradually loses its foreign constituents and passes into a coarse pebbly grit, which is mainly composed of pebbles of white and blue quartz and pink felspar, with occasional fragments of limestone. Mr. Wilson.

The Ardnoe beds, which form the upper portion of the Loch Awe quartzite series of this area, and are well seen at Kilmory Bay,* have not been found in the area under description, none of the synclinal folds being sufficiently deep to bring in these strata.

The outcrops of the Ardrishaig phyllites generally occupy peaty hollows between ridges of the harder quartzite, epidiorite, etc., and for some distance to the south of Eas Daltot these outcrops are few and narrow.

*Op. cit., p. 67.

Mr. Wilson. The black Easdale slates, which a little distance north-east of Eas Daltot come between the Ardrishaig phyllite group and the base of the Loch Awe quartzite, as already described by Mr. Bailey, are not found in the area under description, and the latter series rests—it is presumed unconformably—upon some high member of the phyllite series.

Area between Ormsary Water and Kilberry Head.—For some distance from the sea-board the ground is occupied by phyllites, but further east we reach a broad belt of quartzite composing the base of the Ardrishaig series. Along the shore the phyllites are calcareous, but a little inland we find phyllites free from calcareous matter and interfolded with bands of fine-grained light brown quartzite. These folded quartzite bands are identical in character with the basement beds of the Ardrishaig series which lie further east, and they probably represent the upper portion of these beds brought up along the crests of isoclinal anticlines.

At the head of the Crear valley, a bed of limestone, about 4 feet thick, of a pale yellow or white colour and somewhat siliceous, is found near the top of the basement quartzites.

Mr. Grabham. *Ellary, Achahoish, and Baranlongart.*—To the west and north of Ellary the rocks are chiefly phyllites of the Ardrishaig series, with occasional quartzite beds similar in character to those found elsewhere in this series. On the west side of Loch Caolisport no further bands of conglomerate like those described last year* have been found, but on the eastern shore a band containing quartz pebbles was noticed in a series of green phyllites at the beach west of Achadh Cul Bhar. Further east, quartzite intercalations increase in proportion until a series of soft impure quartzites is reached which forms most of the ground east of the road as far as the head waters of Baranlongart Burn. At the western side of this series a zone with limestone bands occurs, and may be seen just west of the road about three-quarters of a mile E.N.E. from Achahoish, and again on the same line of strike at An Torr and south of Baranlongart House. Each band is liable to vary in character considerably, some parts being almost pure limestone, while others are impure and sandy or mixed with thin hard siliceous seams, such as are well seen at An Torr and in Baranlongart Burn, near the Fort. A limestone of similar character is exposed at different points towards the east, but usually only in streams.

OLDER INTRUSIVE IGNEOUS ROCKS.

Buchaille Etive Mòr, between Glencoe and Glen Etive.—A thin band of hornblendic rock, two or three feet thick, was noticed in the River Coupall, 1,250 yards above its foot, and both from its petrological characters and its relations to the banding of the schists, it seems possible that it represents one of the older series of intrusions (older than the Old Red Sandstone).

* See Summary of Progress for 1904, p. 66.

Ellary, Achahoish, and Baranlongart (Knapdale).—Green hornblendic rocks of igneous origin occur throughout the area and form particularly large masses towards its eastern margin, near An Goblach, which owes its prominence to a sheet of epidiorite making an outcrop nearly a quarter of a mile broad. Most of the types met with this year are non-porphyritic, varying considerably in texture, from compact varieties to coarse-grained rocks with ophitic plates of hornblende which sometimes attain the breadth of an inch and enclose felspar tables a third of an inch in length. Such a rock is seen in a cutting recently made for the road near Achahoish Church. Some garnets were met with in an intrusive sheet a quarter of a mile west of Loch a' Chaoruinn. Mr. Gra[illegible]ham.

Area between Castle Sween and Eas Daltot.—In this area there are probably not more than two major sills, which have, however, been repeated again and again by folding, one of which is fine-grained and foliated, and the other much coarser and massive. Where they make crags the two can be readily distinguished even at some distance, for the coarse rock breaks off into numerous subangular blocks, while the finer-grained gives rise to a talus composed of large flat slabs. Mr. Wilson

Area between Ormsary Water and Kilberry Head.—A conspicuous band of massive epidiorite traverses the eastern side of this area and occupies a position a little within the western margin of the zone of quartzite at the base of the Ardrishaig phyllite series.

LOWER OLD RED SANDSTONE.

Volcanic Rocks, together with the associated sediments and Intrusive Rocks.

Glencoe and Dalness Area (Glen Etive).—The mapping of the volcanic series of Glencoe was continued eastwards to the Buchaille Etive Bheag, where the succession was found to be much more complicated than to the west, owing to the frequent alternation of andesite with rhyolite. The rapidity with which a thick succession of andesitic or rhyolitic flows thins out and disappears is here well displayed. The rhyolites are frequently crowded with fragments, chiefly composed of rhyolite, so that they appear at first sight to be clastic, but the matrix is glassy, or devitrified, and often exhibits flow-banding. The andesites also contain fragments, but as a rule only at the top and bottom of each flow. True tuffs and agglomerates, generally accompanied by thin shales and sandstones, form but a very small part of the series. Mr. Muff

On the eastern flanks of the Buchaille Etive Bheag the Ben Cruachan granite is intruded into the volcanic series and has caused considerable contact alteration round its margin.

Outside the boundary fault of the volcanic area (the Glencoe fault) two small patches of conglomerate have been observed lying on an uneven surface of the schists. One of these patches,

Mr. Muff. situated at a height of 2,500 to 3,000 feet on Sgor nan Fiannaidh, north of Glencoe, consists of subangular and angular quartzite blocks set in a siliceous matrix, and rests on quartzite. The other patch, near the head of Glen Gaoirean (Glen Etive) is a coarse conglomerate made up of large subangular blocks of phyllite mixed with a few small fragments of quartzite, and rests on Ardrishaig phyllites. Whilst both are pierced by plutonic rocks of "Newer Granite" facies, and cut by porphyrite dykes, the former contains fragments of red felsite and porphyritic andesite or porphyrite. In a burn section near Dalness, where the volcanic series rests on quartzite, there is at the base of the volcanic series a coarse quartzite conglomerate similar to the above. These patches of conglomerate may therefore be regarded as outliers of the basal conglomerate of the Lower Old Red Sandstone, and they throw further light on the uneven character of the surface on which the Lower Old Red lavas were poured forth.*

Mr. Bailey. *Southern side of the River Leven.*—No sooner does the Glencoe fault cross the watershed to the north of Glencoe than it turns suddenly, almost at a right angle, and runs along the watershed in a general E.S.E. direction. It has been traced in this direction for about six miles until it is cut across, apparently, by the great granite intrusion of the Moor of Rannoch, and along this part of its course it is characterised or accompanied by various peculiar phenomena, viz.† :—

1. It is, in places, occupied by a line of flinty crush.
2. The lavas generally dip steeply away from it, and in the immediate vicinity are not infrequently overturned.
3. A zone, about a mile broad, characterised by intrusions of granitoid porphyrite, follows the course of the fault. This rock rarely transgresses on to the downthrow side of the fault, but upon the external or upthrow side it occurs in extreme abundance, in large and small masses, which are frequently accompanied by permeation phenomena. These masses occasionally occur in dyke form along the fault, and in several other cases terminate against it abruptly with chilled margins. The zone of the intrusions follows the fault round the rectangular bend already mentioned.
4. The numerous N.N.E. porphyrite dykes usually maintain their steep, almost vertical positions, without change, across lavas, fault and granite alike, but occasionally they run for a short distance along the fault, choosing it as an already established line of weakness.

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* A limestone conglomerate resting on the limestone of Lismore was recorded in the Summary of Progress for 1901 (p. 125). It bears the same relations to the schists and to the igneous rocks as those conglomerates described above, and is probably of the same age.

† Some of these phenomena are similar to those already noted by Messrs. Clough and Muff in other districts further south (Sum. of Prog. 1904, pp. 67-69).

Mr. Bailey.

5. A later brecciation, frequently found along the old fault, crosses the dykes without appreciably shifting their outcrops.
6. Along part of its course, the fault plane, which is elsewhere vertical, becomes reversed, and assumes the appearance of a thrust plane, being inclined towards the horizon at angles as low as 50°.

From the above phenomena it is evident—

1. That we have in this area an instance of the overriding of a subsiding area, similar to those described by Suess*.
2. That the granitoid intrusion must have accompanied the subsidence, the igneous matter welling up on all sides of the subsiding area.
3. That this great subsidence, measured by thousands of feet, was entirely accomplished within the period of igneous activity in this district. Its date can be fixed as later than that of the lavas, contemporaneous with that of the granitoid porphyrite, and earlier than that of the great dyke-intrusions.

On the depressed side of the above fault the natural base of the volcanic group is frequently exposed, being brought up either by a steep rise towards the elevated side, or else by a fold, in the upper limb of which the beds are reversed, and dip towards the elevated side. A thin band of sediment always occurs between the schists and volcanic rocks, but it varies in character, being composed of conglomerate in the west and in the east of breccia and shale.

Two sets of felsite dykes have been met with, one, which is certainly older than the Glencoe fault and the granitoid porphyrite, and another of later age, which is sometimes represented by veins traversing the crush-rock of this fault. Both sets are earlier than the porphyrite dykes, and there is not, as a rule, any means by which they can be distinguished. It is probable, however, that a considerable proportion of them belong to the older set, for these dykes exhibit no uniform N.N.E. direction, such as almost invariably characterises the quartz porphyries and porphyrite dykes. One of the older felsite dykes, which runs east and west and is generally flanked by a narrow border of hornfelsed schist, is found within the granitoid intrusion of Meall Dearg, and will, in the map, appear as if it were later than it, though on the ground it is clear that it is earlier, as the granitoid rock is chilled against it.

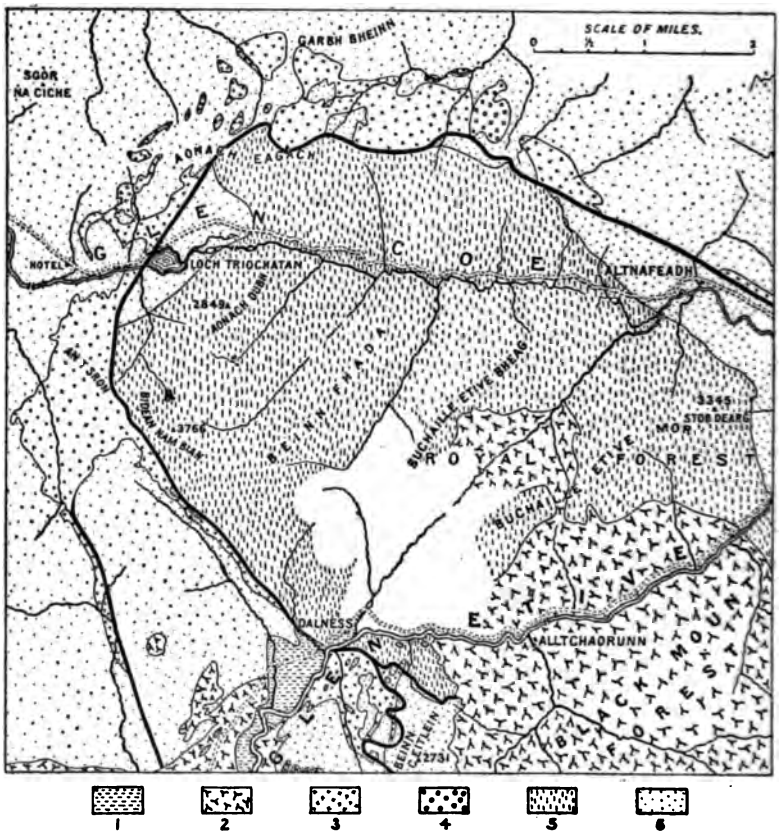
In the district north of the Glencoe fault, another set of small intrusions, certainly earlier than the great dyke-phase, is represented by numerous horizontal or slightly inclined sheets of hornblende vogesite, which are cut by the porphyrite dykes.

* "The Face of the Earth," translated by Hertha B. C. Sollas, Vol. I., pp. 139–143.

Mr. Grabham.

Buchaille Etive Mòr.—South of Lagangarbh a coarse breccia or conglomerate, made up of angular pieces of different varieties of quartzite, rests upon the upturned edges of the schists. Intercalated with this, at a point about 600 yards up the stream,

FIG. 2.—*Map of Glencoe.*



1. River Terraces.
2. Beinn Cruachan Granite.
3. An t-Sron Granite and Granitoid Porphyrite.
4. Diorite-porphyrite older than the An t-Sron Granite.
5. Volcanic Rocks.
6. Schistose Rocks.

Thick black lines indicate faults not younger than the An t-Sron Granite and Granitoid Porphyrite.

south of Lagangarbh, we find a thin flow of dark compact andesite, above which come the great masses of rhyolite and ash forming the crags of Stob Dearg. Among these eruptive rocks we find some thin beds of red sandstone, which show the general dip to be to the south. There are also some agglomerates which vary rapidly in thickness, or thin out entirely. The uppermost member of the volcanic series mapped is a sheet of hornblende-andesite which forms the mid peak of the Buchaille Etive Mòr.

On the Glen Etive side of this mountain the base of the lavas is not seen, as they are truncated by the Alltchaoruinn granite, which has also metamorphosed them to such an extent that it is extremely difficult to distinguish their different types. Mr. Grabham.

The granite referred to has been traced across the watershed and is continuous with that of Lairig Gartain. The common type is a biotite-hornblende-granite (tonalite) in which biotite is the more abundant dark constituent. Towards the margins the quartz decreases and becomes invisible to the unaided eye, while white plagioclase appears to increase, and aplite veins seem also to become more frequent, often penetrating the surrounding rock. In sections along the lower parts of the River Coupall we see the basic margins of this granite, as well as an acid pink granite similar to that of the Moor of Rannoch.

The boundary between the granite and the lavas of Buchaille Etive Mòr is sharp and of a simple character, but that between the granite and the schist, towards the north-west, is complicated by the presence, between the main masses of each rock, of a wide zone of injection breccia and permeation.

A few dykes of rhyolitic character were met with among the schists, and may be earlier than the abundant dykes of quartz porphyry and porphyrite which trend north-north-easterly, and traverse schists, lavas, and granites alike.

Intrusions of Dolerite and Basalt.

Ellary, Achahoish, and Baranlongart (Knapdale).—A large east and west dyke runs past Loch Meadhonach and Ellary, on the west side of Loch Caolisport, while on the east side it extends for some distance south of Baranlongart Burn.

About 300 yards north-east of Loch a' Chaoruinn a mass of dolerite occupies an area of several acres.

Several Tertiary north-westerly dykes were mapped, one of which is seen to cut the east and west dyke on the banks of the Abhainn Mhor, west of Ellary.

Area between Ormsary Water and Kilberry Head (Knapdale).—A few east and west dykes have been found, and also several trending north-west. Most of the latter vary in breadth from 10 to 15 feet, but one, which crosses the Crear Burn below Crear, is 85 feet wide. Mr. Wilson.

PLEISTOCENE AND RECENT.

Glen Leven (Sheet 53).—In the period of maximum glaciation, the Moor of Rannoch formed a centre of dispersion from which the ice sheet radiated, regardless of the surface configuration of the land. The striæ on the hill tops show that the ice travelled nearly parallel with the valley of the Leven and the upper part of Glencoe. It appears, from a study of the distribution of the lateral moraines, that, at a later stage when all the summits were free of ice, the Moor still served as a centre of dispersion, the ice diverging from it sending one arm down Glencoe Mr. Bailey

Mr. Bailey. and another down the valley of the Leven. The Glencoe stream must have been the larger of the two, for it sent a branch northward round Stob Beinn a'Chrùlaiste to join the Leven glacier, as shown by the northern inclination of the lateral moraines which have been preserved in the cross valley. This is just what might be expected from the fact that the Moor of Rannoch is much less circumscribed by higher ground on the north than on the south.

Knapdale, Cruach Lusach Area.—The glacial striæ indicate three different directions of ice flow, namely, S.S.W., W.S.W., and W.N.W., but at what periods and under what conditions these striæ were produced we do not know. There is no evidence of later valley glaciation, nor any sign that the formation of the 100-feet raised beach was interfered with by ice.

Mr. Wilson. *Area between Castle Sween and Eas Daltot.*—The glacial deposits are seldom widespread, but the peat in the hollows between the rock ridges is occasionally seen to rest on boulder clay. In the Abhainn Mhor valley, east of Clach-druim, a larger mass of this material is found, and in one locality in the west bank of the stream the following section was observed:—

Laminated boulder clay with small stones - - -	9 feet
Well bedded gravel - - - - - - - - -	4½ „
Stiff grey boulder clay, base not seen - - - -	6 „

Area between Ormsary Water and Kilberry Head.—The Crear valley is filled with thick boulder clay. At Stotfield Bay the inner margin of the 50-feet raised beach has been carved out of this deposit, and numerous sections show that it is a reddish-brown sandy clay with a few small stones, and at least 100 feet thick.

A well-defined raised beach extends along the coast at a height varying between 30 and 50 feet above the sea level. It is chiefly a bench of erosion, and for a considerable distance the bottom of the rock margin on its inland side is not, on the average, more than 30 feet above sea level, but when it is overlaid by beach deposits, as at Port Cill Maluaig and Miller's Bay, its surface reaches the 50-feet contour.

The 100-feet raised beach is only found in small patches where it has been carved out of glacial deposits. Near Rudha Cill Maluaig it makes a grassy platform, on which stands the site of the chapel and burial ground of Cill Maluaig.

Mr. Grabham. *Ellary, Achahoish, and Baranlongart.*—Glacial striæ, pointing about S.S.W., parallel to the direction of the rock ridges, were observed in several places.

The 100-feet raised beach forms large sandy flats at Achahoish and Baranlongart, and a lower beach, about 30 feet above the sea level, has also formed good land for cultivation.

Peat exists in abundance, but generally only in small basins, on both sides of Loch Caolisport. The largest area, nearly half a square mile in extent, occurs between the Abhainn Mhor and Ellary Burn,

ECONOMICS.

Glencoe, Glen Etive, and Glen Leven Area.—The whole of the ground is used as deer forest, with the exception of a few square miles on the east side of Glen Etive, south of Dalness.

Peat, filling up the little hollows between the morainic mounds, forms an important source of fuel, but most of these patches are too small to be mapped.

An abundant supply of road metal is obtained from pits dug in the moraines near the roadside, but none of these holes exceeds 20 feet in depth.

An important scheme is in progress to utilise the great natural resources of the district for supplying water power. The principal valleys have in geologically recent times been over-deepened with regard to their minor tributaries, which now constitute a system of hanging valleys. A rapid drop in level is experienced in passing from the old to the new valley system, and this characteristic, combined with the great rainfall, renders the district suitable for such an enterprise. At the head of the Leven, the hanging valley system merges into the Moor of Rannoch, at an elevation of about 1,000 feet above the sea, and it has been decided to make on the moor a large reservoir to supply a power-station situated near the head of Loch Leven. Messrs. Thomas Meik & Sons, C.E., Edinburgh, have kindly furnished the following account:—

"The Loch Leven Water and Electric Power Company has acquired all the water rights over the Blackwater Lochs, comprising Loch a' Bhaillich, Lochan an Salach Uidhre, and Lochan Inbhir, the catchment area being about 55 square miles in extent. At the lower end of Lochan Inbhir a concrete dam will be constructed of a length of over half a mile, and will raise the level of the water above 76 feet. When the new reservoir is full it will form the largest artificial stretch of water in Great Britain, and will stretch eastwards to within 1½ miles of the West Highland Railway at a point about midway between Rannoch and Corrour stations. The new reservoir will be about 8 miles long, and will hold about 18,000,000,000 gallons of water.

"From the dam a conduit, 3½ miles long, is led along the hillside, following the contour of the ground as much as possible, to a penstock chamber almost 1,000 feet above sea-level. From thence the water is conveyed in steel pipes down to the turbines.

"With the water and head available, the new works will be capable of developing 24,000 effective H.P., working night and day over as long a drought as one is likely to have in one of the wettest districts of Scotland."

Area between Castle Sween and Eas Daltot, and between Ormsary Burn and Kilberry Head (Knapdale).—At the foot of the Coire Mhàim, near the head of the Ormsary Water, a metalliferous vein, about eight feet wide, intersects the quart-

Mr. Wilson. zites at the base of the Ardrishaig Phyllite Series. The gangue is composed of dolomite with quartz and albite, and contains scattered specks of chalcopyrite and zinc blende in tolerable abundance.

There are no quarries excepting shallow ones, used for obtaining road metal or material for building stone dykes, etc.. Gravel is chiefly employed for the roads, but occasionally epidiorite, basalt, reef-quartz, and quartzite are used.

On account of the depth and extent of the boulder clay there is a considerable area of good agricultural land in the Crear valley, and the fields are large and generally well drained. But in the past a much larger area was cultivated, and South Knapdale must have had a considerable agricultural population, as is proved by the numerous abandoned crofts. Fifty to seventy years ago there were four corn-mills—now all in ruins —at Muileann Eilean Bagh, Ormsary, Miller's Bay, and Carse, which ground the corn grown in the district, and it is reported that some surplus meal was exported to Ireland. The present population is small and scattered, and most of the houses are situated not far from the sea-board.

Messrs. Bailey and Grabham. *Cruach Lusach Area, together with the Ellary, Achahoish and Baranlongart Area.*—The whole district is under sheep save some small woods, and some cultivated stretches of raised beach. During the summer many visitors are accommodated at the farm houses, the district being very picturesque and tolerably accessible from Glasgow and the neighbouring towns.

The coastline of the district is much indented by sea-lochs or fiords, which represent the submerged terminations of an intricate valley system resulting from processes of erosion, regulated by the complex geological structure of the region. The beauty of the coastline and the natural harbours of the district attract many yachtsmen.

The roads are for the most part restricted to the flat coastal strip of the 25-feet raised beach, and many of the old farm houses, built upon the 100-feet beach or elevated patches of drift, have been deserted in favour of new buildings by the roadside. The material for mending the roads is chiefly furnished by small quarries in quartzite and epidiorite.

2. North Highland District—Embracing Parts of Ross, Inverness and Caithness.

Dr. B. N. Peach, F.R.S., District Geologist, and after his retirement Mr. L. W. Hinxman, B.A

Mr. L. W. Hinxman, B.A.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A. B.Sc. } Geologists.
Mr. R. G. Carruthers.
Dr. J. Horne (Acting).

HIGHLAND METAMORPHIC ROCKS.

Glen Strath Farrar, Glen Orrin, and Glen Meig.

The field work during the past season in Central Ross-shire and Inverness-shire has been carried on in the wild mountainous region that surrounds Loch Monar, the heads of Glen Strath Farrar and Glen Orrin, and the upper part of the valley of the Meig; the area surveyed extending northwards from the watershed between Glen Cannich and the basin of the Farrar to the southern slopes of Sgurr a' Mhuilinn. Mr. Hinxman.

Within this area are some of the highest mountains in Rossshire, Sgurr na Lapaich and An Riabhachan south of Loch Monar, and Sgurr a' Choir Ghlais between the Farrar and Glen Orrin, all reaching heights of over 3,500 feet.

With the exception of a small extent of sheep ground at Scardroy, the whole district is deer forest, and save for a few widely scattered keepers' houses and a patch of cultivation at either end of Loch Beannachan, all uninhabited waste land.

The metamorphic rocks with which the entire area under consideration is occupied belong to the two great groups of schists and gneisses enumerated in last year's Summary, and present, in the main, the usual lithological characters of those rocks as described in former Reports.

Briefly to recapitulate the classification adopted in the Summary for 1904, the groups are as follows:—

(a) Complex gneisses of Lewisian type.
(b) Moine Series
  (b^1) Quartz-biotite-granulites (siliceous Moine schists).
  (b^2) Garnetiferous mica-schist or pelitic gneiss (muscovite-biotite-gneiss).

A most important feature of the past season's work has, however, been the discovery, in different and widely separated areas of the complex gneiss (a), of a series of altered sedimentary rocks, including crystalline limestones, calc-silicates, and brown mica-schists, often graphitic. These are frequently associated with eclogites, in addition to the ordinary hornblende and hornblende-biotite gneisses of the complex.

The striking similarity, both in lithological character and in association, of these rocks to certain altered sediments mapped in the Lewisian gneiss of Glenelg by Mr. Clough* goes far to confirm the views expressed in the Reports for 1898, 1900-2-4, as to the Lewisian age of these inliers of complex gneiss.

Further evidence of the unconformable relations of the different members of the Moine Series (b) to these inliers has been gathered in all parts of the area; and the occurrence noted, both along the marginal portions of the siliceous granulites

* Summary of Progress for 1897, p. 37.
" " " 1898, p. 14.
" " " 1901, p. 96.

Ir. Hinxman.

(b^1), and in isolated patches resting upon the gneiss (a) of a rock having all the appearance of a sheared conglomerate.

The largest mass of rocks of Lewisian type yet mapped east of the Moine thrust occupies the valley of the Meig from a point four miles above Scardroy to Inbhir-chorainn at the foot of Loch Beannachan, and sweeps northwards and eastwards over Cairn Chaorain, Leanuidh, and the head of Glen Meinich to the northern flanks of Sgurr a' Mhuilinn. On the south side of Loch Beannachan the banded acid and hornblendic gneisses (a) are, as described in last year's Summary, in contact throughout with the pelitic gneiss of the Moine Series (b^2), but on following the northern margin of the inlier from Carnock up the steep slope of Meall Feochaig the observer finds that margin transgressing the boundary between the two groups of the Moine Series, so that from a point about half a mile below the summit ridge of the hill the gneiss is continually in contact with the siliceous member (b^1) of that series. The two formations can be traced in contiguity round the ends of a series of sharp complex isoclinal folds, and though the actual junction is nowhere exposed, the two rocks can be seen within a few feet of each other on the summit of the ridge that overlooks Loch Beannachan on the north.

Thin bands of limestone have been observed at two localities in this area—in the bed of a small stream falling from Creag Ghlas into the head of Gleann Meinich, and in the deep ravine cut by the large burn which falls into Loch Beannachan, half a mile east of Scardroy Lodge. The limestones are coarse-grained, granular crystalline, and banded, but not finely schistose. They contain flakes of dark green biotite, and, in the specimens from Gleann Meinich, small crystals of bright green amphibole are present. The limestones in the second locality are associated with banded hornblendic gneisses, remarkable for the large amount of yellow epidote which they contain. In the same section, and within a short distance of the limestone, also occur two somewhat peculiar rocks of a green colour. The macroscopic characters of one of these (12,393) is thus described by Dr. Flett: "A rock with fine-grained pale green bands resembling a calc-silicate-hornfels, and coarser grained folia with dark green hornblende, pale felspar and scapolite which are not very different in appearance from a medium-grained hornblende gneiss. The scapolite tends to become red on decomposition and thus becomes visible on the surface of the specimens." The microscope reveals the presence of pale or colourless augite which is very abundant in certain parts, and the rock is named by Dr. Flett a "scapolite-pyroxene-gneiss." The second rock (12,396) is bright green and massive. It is described as a "pyroxene-epidote" rock, consisting of granular yellow epidote, often zonal in polarised light, and very pale green perfectly fresh augite (omphacite or diopside) together with a little felspar and sphene.

A belt of ground in which bands of dark hornblende-gneiss with a persistent N.N.W. trend make up the greater portion of the rock, extends northwards from the head of Loch Beannachan.

These bands may represent early basic dyke-intrusions, probably repeated by folding, and are comparable to the hornblende-schist bands of the Shieldaig gneiss area, where the intrusive nature of the basic rock has not been so completely obliterated by subsequent movement. Associated with these hornblende gneisses is a narrow lenticular mass of thoroughly foliated ultra-basic rock. Mr. Hinxman.

The system of folding over the greater part of this area is regular and at high angles, the axes of the folds having a general N.N.W.–S.S.E. trend. Further examples have been met with in Coire Bhuic of unobliterated original structures in the Lewisian gneiss, with which the foliation planes of the overlying siliceous rocks of Moine type are distinctly in discordance.

A smaller inlier of the complex gneiss, surrounded by the siliceous granulites (b^1) has been mapped on the northern slopes of Gleann Meinich; and on the south side of Glen Orrin the large mass, whose eastern extension was surveyed in former years, has been carried westwards to the head of Allt a Choire Dhomhain. The complex isoclinal folding of the region is excellently illustrated on the bare crags at the head of An Gorm Loch, where it is clearly evident that the banded acid and hornblendic gneisses of the Lewisian inlier are in contact with a lower zone of siliceous granulites (b^1), upon which successive outcrops of pelitic gneiss (b^2) rest in a series of isoclinal synclinal folds.

Glen Fhiodhaig to Loch Monar.—The whole of the upper part of Glen Fhiodhaig is occupied by the two members of the Moine Series. The strike of the rock is, with the exception of a small area on Creag Dubh Mor, uniformly in a N.E. direction. The beds are inclined at high angles and have been subjected to deep isoclinal folding. On the hill one mile east of Carn Gorm a mass of garnet-amphibolite appears within the massive siliceous granulites (b^1). The junction of the two rocks is visible in several places and the margin of the amphibolite is seen to cut what appear to be the bedding-planes of the sedimentary rock. The edge of this basic mass is fine-grained, the central portions coarse and unfoliated. Mr. Carruthers.

The wide area of complex gneisses mapped last year in Gleann Fhiohaig has been found to continue southwards in a narrow belt along the valley of the Allt a Choire Fhionnaraich to the shores of Loch Monar a little to the east of Strathmore. The group of altered sediments already referred to as closely similar to those found in the Lewisian gneiss of Glenelg is well developed in this belt, and includes crystalline limestone with graphite, calc-silicate rock, graphite-schist, and a brown mica-schist.

Excellent sections showing the relations of the siliceous Moine-schists to the different members of the Lewisian complex are displayed along the course of the Allt Choire Fhionnaraich, where from a point one and a quarter miles above Lub' an Inbhir to half a mile below Loch a' Chlaideamh, the siliceous schists are seen in contact successively with calc-silicates, horn-

r. Carruers. blendic gneiss, graphite-schist, and finally again with the hornblendic gneiss.

Another good section at right angles to the strike of the rocks is exposed in the Allt Chreagan Bhuidhe, a tributary of the last-named stream. Here the limestone and graphite-schist are associated with orthogneisses of hornblendic type. The crystalline limestones appear again on the hillside half a mile above Reidh Cruaidh, having been shifted about a mile to the south-west by a branch of the great Strathconon fault.

r. Crampn. *Area South of Strathmore and Loch Monar.*—In the area mapped by Dr. Crampton to the south of Strathmore and Loch Monar, the pelitic gneiss (b^2) of the Moine Series is developed in two main outcrops. The eastern boundaries of one of these, which covers the head of Strathmore, has been traced southwards from Meall Mhor to Loch Gobhlach, whence a change in the strike carries it westwards to Loch Calavie. The other extends in a west-south-western direction from Garbh-choire to the southern edge of Sheet 82, forming the lofty ridge of Sgurr na Lapaich and An Riabhachan.

The gneiss presents the usual lithological characters of this member of the Moine Series, and is accompanied in both areas by intrusions, more or less foliated, of the garnet-amphibolite frequently observed in other areas.

Rocks of the siliceous granulitic type (b^1) occupy most of the lower ground. They contain none of the intercalations of biotite-schist which characterise the upper siliceous series in areas further to the north, though infolds of the presumably overlying pelitic group occur along certain lines of strike.

Thick veins of white muscovite-pegmatite are abundant, and show a varying amount of deformation and granulitisation. On Beinn Dubh an Iaruinn, where the original bedding planes, almost at right angles to the foliation, are well preserved, the pegmatites mainly follow the bedding, and where this has been most affected by subsequent folding the veins share in the sharp plications and assume a more granulitic character. A similar phenomenon has been observed in connection with the augen-gneiss of north Ross-shire.

The complex gneisses of Lewisian type are well developed in the Monar area and occur in four separate inliers, two on either side of the great Strathconon fault zone which crosses Loch Monar.

r. Flett. Before entering upon a description of the several areas, it will be useful to quote the result of a preliminary examination by Dr. Flett of a series of rocks from these inliers submitted to him by Dr. Crampton.

"This collection of rocks includes a great diversity of types, most of which are crystalline gneisses presumably of plutonic origin (ortho-gneisses); while others are marbles and sedimentary gneisses (paragneisses). Some of the latter show evident signs of contact alteration induced probably by the action of the former.

"The commonest orthogneisses are hornblende-gneisses charac-

terised by the abundance of common green hornblende like that which is usual in granites and diorites. They contain also much yellow epidote with orthoclase, plagioclase, quartz, sphene, and the usual minor accessories. The relative abundance of their constituents varies greatly; many of them are well banded, while others are nearly massive. In a few of these rocks a pale green pyroxene occurs and may be abundant along with epidote and quartz in certain lenticles or knots (pyroxene-epidosites). Biotite is more frequent and may preponderate over hornblende. A few typical biotite-orthogneisses are included in the collection. In them also epidote is a very important accessory. Dr. Flett.

"The eclogite from An Cruachan (12,421) is composed of red garnets with pale green hornblende, augite of similar colour and quartz. Apatite, sphene and pyrite are also present, but epidote does not occur in the section.

"The ultra-basic rock (12,415) which may represent the peridotite dykes intersecting the Lewisian gneiss, is a dark green silky talc-chlorite-schist which contains a considerable amount of calcite.

"Another rock, the affinities of which are doubtful, comes from Allt Riabhachain (12,416). It may correspond to the pyroxenites of the Lewisian gneiss west of the Moine Thrust. It consists of pale brownish-green amphibole, green augite, biotite and carbonates.

"The second group of rocks from these inliers includes the marbles and sedimentary paragneisses. Two specimens of granular crystalline marble (12,417, 12,423) are greenish coloured from the abundance of calc-silicates. These are tremolite and pale green malacolite; a silvery white or very pale yellow uniaxial biotite occurs also with small amounts of untwinned felspar, quartz, sphene and apatite.

"There are also muscovite and biotite-schists (12,475, 12,429), not readily to be distinguished from rocks of the same kind in the Moine Series. Of special interest is a well foliated garnetiferous biotite schist (12,422) from the eastern shoulder of An Cruachan, with much graphite and large crystals of andalusite. The presence of this last mineral would indicate that this rock has suffered thermal metamorphism."

The first of these inliers to be described occupies the low ground between Beinn Bheag and Loch Monar, to the S.E. of Pait Lodge, and is in continuation with the area of similar rocks mapped by Mr. Carruthers on the north side of the loch. The rocks found in the area under consideration embrace acid, hornblende-biotite, and biotite-gneisses, with bands of crystalline, limestone and epidotic calc-silicate. The general strike of the gneiss towards the foot of Beinn Bheag is S.W. and the siliceous granulites (b^1) which form the higher ground have a similar strike, but the boundary between the two formations lies at right angles to that direction, thus conveying the idea that the rocks of (b^1) are resting unconformably upon the complex gneisses. Dr. Cramton.

The next inlier, about one square mile in extent, covers the northern and eastern flanks of An Cruachan, the summit of the

r. Cramp- hill being formed of siliceous granulite (b^1). This area reaches a
n. much greater elevation than that last described, and lies on the line of a powerful "ruck" or axis of sudden plication, which passes northwards through Bidean an Eoin Deirg. In addition to the usual types of orthogneiss, this inlier contains eclogite closely associated with highly graphitic schist, and a brown biotite-schist which has some resemblance to the pelitic gneiss of (b^2). The An Cruachan inlier is surrounded on all sides by siliceous rocks of the Moine Series (b^1), and the transgression of these schists over the different members of the Lewisian complex is clearly seen, the former being in contact successively with the graphite schist, the biotite-hornblende gneiss, and the brown mica-schist.

The western boundary of the third inlier to be considered is formed by the Strathconon fault, by which the Lewisian gneisses are brought into conjunction with the Moine granulites of Beinn Bheag for a distance of nearly two miles.

The area lies at the foot of An Riabhachan, and is traversed by the headwaters of the Riabhachan burn, in which good sections of the rocks are displayed.

The ground rises to the south and east, and the margin of the gneiss is coterminous in these directions successively with the two members of the Moine Series. The line of junction with the quartzose rocks of (b^1) is at right angles to the general strike, but conforms to the irregularities of the ground in such a manner as to indicate the superposition of the Moine rocks upon the gneisses of the inlier. The mapping also shows an overlap of the pelitic sediments (b^2) over the siliceous schists (b^1) with reference to the underlying gneiss in passing from N.E. to S.W. Included in this area with the ordinary acid and basic gneisses are ultra-basic rocks containing talc and carbonate bands; also crystalline limestones similar to those previously described.

The mapping of the largest inlier of Lewisian rocks south of Loch Monar is still incomplete along the eastern margin. The area surveyed extends from the Uisge Misgeach burn at an elevation of 300 feet, nearly to the 3,000 feet contour line on Sgurr na Lapaich, the gneiss showing a vertical extension of over 2,000 feet. The gneiss forms the floor of the Garbh Choire on the east side of Sgurr na Lapaich, and of Toll a' Lochain, the deep corrie that lies between that mountain and An Riabhachan. Along the eastern shoulder of Sgurr na Lapaich the gneiss rises in huge cliffs which have all the massive appearance characteristic of the Lewisian rocks in the landscapes of the N.W. Highlands. The gneiss is in contact with the pelitic group (b^2) of the Moines at all elevations over 1,750 feet, and with the siliceous zone (b^1) at lower levels.

At a height of 1,250 feet, isolated exposures of a rock having a strong resemblance to a conglomerate are found resting upon the gneiss. In this rock masses of hornblendic gneiss and smaller fragments, resembling pebbles, of more acid material are scattered through a siliceous matrix of ordinary Moine schist type. It is probable that these isolated masses represent outliers of a some-

what similar rock mapped a short distance further to the east, and along the same line of strike by Mr. Anderson, and described in a later paragraph. Dr. Crampton.

The belt of gneiss of Lewisian type referred to in the preceding paragraph forms the lower part of the steep eastern face of Sgurr na Muice north of the Farrar, and is succeeded by a band of pelitic Moine Gneiss (b^2) of remarkably uniform thickness, which follows the cliff face for about a mile, forming a well-marked feature. It is succeeded above by 400–500 feet of siliceous granulite (b^1) which extends in an unbroken mass for more than a mile to the west. The lower band of pelitic gneiss dies out to the south, so that the siliceous rocks pass directly on to the older gneiss. They also border it continuously on the east and extend in a belt more than a mile in breadth to a point north of Loch Toll a' Mhuic. Further to the east they are succeeded by an alternating series of siliceous and micaceous rocks, and these by a broad band of pelitic gneiss running north and south through Loch a' Mhuilinn. Mr. Anderson.

The siliceous schists in the extreme west of the area contain great numbers of pegmatite veins. These have frequently a definite trend to N. 20°W., but at other times their course is quite irregular. Dr. Flett describes a specimen from one of these veins as a coarse-grained mixture of orthoclase and quartz with a little plagioclase.

Glen Strath Farrar.—The complex gneisses of Lewisian type mapped last year on the north side of the Farrar have been traced across the valley in a south-western direction. They include hornblende gneisses; acid gneisses which probably represent sheared pegmatites; and other rocks which much resemble the siliceous portions of the surrounding Moine Schists (b^1).

In addition there are bands of calc-silicate, seemingly made up of tremolite and actinolite, and in one case a band occurs which is described by Dr. Flett as malacolite rock.

At various points along the western margin of this belt, south of the River Farrar, a formation is found at the base of the Moine Series which much resembles a sheared conglomerate. The fragments which suggest pebbles consist for the most part of siliceous material probably derived from the more acid portions of the adjacent complex gneiss. It is doubtful whether any pebbles still remain that have been derived from the hornblendic portions, the more finely divided material from the latter being more likely to enter into the composition of the matrix, which is often found to be more micaceous than the pebbles, while any such fragments that may have existed have been crushed by the shearing movements. Traces of conglomerate have also been found in the same position with regard to the Moine Schists and complex gneisses on the west side of Sgurr na Muice. Although the fragmental rock has not been seen in actual contact with the margin of the gneiss, there seems little doubt that it has a general relation to it. The matrix of this conglomerate is at one point noticeably epidotic.

FAULTS.

Hinxman and Dr. Campton.

The great line of dislocation which passes through Strathconon and Gleann Chorainn into the head of Glen Orrin, has been followed south-westwards to the shores of Loch Monar at Lub an Inbhir. It appears on the further side of the loch at Auldfearn and continues to the S.W. in a remarkably straight line, passing out of the area represented on this map a little to the west of An Riabhachan. It is accompanied by many minor faults and by the usual amount of disturbance and disintegration. In the upper part of Glen Orrin the zone of stained and brecciated rock is in places nearly half a mile in breadth. North of Loch Monar the minor faults are chiefly developed on the eastern side of the main dislocation, but to the south are more common on its western margin. It is worthy of note that the minor faults on either side converge towards the main fault in opposite directions, those on the eastern side pointing to the south while those on the western side converge in a northerly direction.

Horne.

The Findhorn Basin.—The area surveyed in the basin of the Findhorn forms a narrow strip extending westwards from Press south of Findhorn Bridge to Beinn Bhreac (1,797 feet) on the watershed between that river and the Nairn. The tract lies to the north of the Kyllachie Burn—an important tributary which joins the Findhorn from the west.

The rocks entering into the structure of the area form the southern prolongations of those referred to in the report for 1904 (p. 80). Owing to the covering of peat on the plateau between the Nairn and the Findhorn and the accumulation of drift in the valleys, the exposures of solid rock are not numerous. Those embrace (1) siliceous quartz-biotite granulites, (2) flaky muscovite biotite schists occasionally garnetiferous, (3) schists of an intermediate type, frequently massive with quartz, felspar and biotite, and (4) small exposures of crystalline limestone with bands of mica-schist. The best exposures of the first type occur on the watershed about four miles west of the Findhorn Bridge, where they appear as flaggy, banded and granular gneisses with a north-easterly dip at high angles. They are traceable southwards to the Kyllachie Burn about three miles west of the Findhorn, where the strike is at right angles to that on the hills to the north. It is evident that in this portion of the plateau the schists exhibit marked changes in strike.

Immediately to the west of the siliceous Moine-schists just described there is a broad zone of flaky, muscovite biotite schist, the eastern boundary of which has been traced southwards to the Caochan Breac, one of the tributaries of the Kyallachie Burn. A feature of this zone is the presence of quartzo-felspathic knots and lenticles, which are folded with the schists and apparently have no connection with the pegmatites belonging to the later granites of the district. The schists of intermediate type (3) are well developed on Carn na Scannachoille and by the road-side

west of Dell of Morile on the west side of the Findhorn valley, where they appear as massive and flaggy quartz biotite gneisses. Of special interest are the small exposures of limestone in the quarry on the hill slope (Creag a' Bhealaidh) west of Kyllachy Lodge and in two small excavations on the west side of Carn na Seannachoile. Two varieties are represented in alternating bands, one consisting of white crystalline granular limestone, the other of marble of a green tint owing to the presence of calc-silicates. These have not been traced beyond these exposures, and their relations to the surrounding schists are obscured by peat and drift. Not far to the north-east of the quarry on Kyllachy Hill there is an outcrop of brown mica schist differing in character from the normal pelitic schist of the district. Dr. Horne.

In a tributary of the Allt a' Mharcaich that joins the Kyllachie Burn from the north, a well-marked fault traverses the plexus of granite and schist and produces considerable brecciation and staining of the rocks. As this dislocation has a N.N.E. trend it is not improbable that it may be an offshoot from the great fault lower down the Findhorn basin between Polochaig and Ruthven (see Report for 1904, p. 84).

Carrbridge Area.—The area mapped by Mr. Carruthers to the N.W. of Carrbridge is chiefly included in the high peat covered plateau which forms the watershed between the Findhorn and Dulnan rivers. The very few rock sections exposed on this plateau exhibit the pelitic gneiss of the Moine Series, while the south eastern slopes between Creag a' Bhainne and the Slochd Mòr are occupied by the siliceous granulites. Mr. Carruthers.

In the railway cutting east of Ardounan, as well as on the side of the Carrbridge road near at hand, occur bands of much decomposed gneiss in which biotite is the chief constituent, muscovite being also present. Within these bands are large "augen" of unfoliated gabbro showing ophitic structure. The edges of the augen are more or less foliated, and appear to pass into the surrounding gneiss. It is possible that these gneiss bands may be due in whole or in part to the shearing of an igneous rock, the less altered portions of which are represented by the gabbro "augen."

The greater part of the area surveyed by Mr. Anderson on the north side of the Dulnan and N. and N.E. of Carrbridge, is occupied by the rocks of the Moine Series. The predominant type is a siliceous granulite, somewhat coarse or even granitic in texture, reddish in colour, and containing a good deal of felspar. The rocks throughout most of the area are also much penetrated with veins of granitic material. Mr. Anderson.

An oval area of micaceous gneiss, similar in character to the belt of pelitic gneiss that follows the county boundary to the north, has been traced between Ruighmagaig and Achtateang. The rock is not visibly garnetiferous and contains bands of exceedingly poor quartzite. A quartz vein occurs in the siliceous series near the head of the Rychraggan burn, which at one point is at least twelve feet in thickness, and contains traces of iron pyrites, hæmatite, and galena.

r.
nderson. In the ground to the east of that just described, there is an abrupt transition from the rocks of ordinary Moine type to a series of rocks different in character from anything yet observed in this particular area.

The series includes the following types:—

(1) Quartzite of a much purer and finer grained type than that of the ordinary siliceous Moines of the area.
(2) Fine grained grey biotite schist, different from the pelitic or muscovite-biotite-gneiss.
(3) Micaceous kyanite-gneiss, with abundant kyanite and weathering with a characteristic brown colour.
(4) Highly crystalline limestone, associated with tremolite and actinolite schist.

Mr. Anderson suggests the possibility that the quartzite (1) may represent the Central Highland or Banffshire Quartzite, but considers that (3) and (4) show points of resemblance to rocks found in the Lewisian Gneiss area of Glenelg, and also in Glen Urquhart. The limestone (4) differs from the normal type of the Banffshire limestone, but resembles the latter where altered by thermo-metamorphism due to the Newer Granite, and may possibly owe its present character to the effect of similar intrusions not far to the north.

CAITHNESS.

r. Peach
id Dr.
rampton. During the autumn Dr. Peach and Dr. Crampton resumed field work in Caithness (Sheet 116) north of the area referred to in the Summary of Progress for the year 1900, where they mapped a belt of ground extending from Dunnet Head in the north to Freswick and Sinclair's Bay on the east coast.

MIDDLE OLD RED SANDSTONE.

With the exception of the promontory of Dunnet Head, which is composed of strata, presumably of Upper Old Red Sandstone age, the remainder of the surveyed area consists of sediments belonging to the Orcadian or middle division of that system. The members of the latter division comprise the normal Caithness flagstones with subordinate masses of red sandstone. They yield the characteristic fishes *Thursius macrolepidotus* and *Coccosteus minor* which have been kindly determined by Dr. Traquair, and must therefore be grouped with the Middle or Thurso zone of the Caithness sequence.

The structure of the middle Old Red Sandstone area, which lies to the east of the great fault crossing the county from Bower Station by Dunnet Village to the sea coast at Brough, is a continuation of that already described in the Annual Summary for 1900, p. 68. Irrespective of minor folds the strata form an elongated dome in the west, and a shallow syncline in the east; each having approximately a north and south axis. The anticlinal axis passes through Watten in the middle of the county

to Ham on the north coast, while the synclinal axis trends from Ackergill at the southern angle of Sinclair's Bay northwards by Keiss to Freswick. The beds in both folds are steeper on one side than the other (viz., on the west limb of the arch and on the east limb of the trough). Besides these major folds there are several minor flexures with north and south axes along which the beds are much puckered, overfolded, and often overthrust from the east. The axial planes of all the folds are therefore not vertical, but dip towards the east and are consequently shifted by the east and west faults. Dr. Peach and Dr. Crampton.

UPPER OLD RED SANDSTONE.

The rocks of Dunnet Head consist of a succession of red and yellow sandstones, shales, marls, and mudstones, often more or less calcareous. The sandstones are extremely false-bedded and contain numerous clay galls, and the shales are often sun-cracked, and give evidence of a considerable amount of contemporaneous erosion. No evidence has been obtained as to the original relations of these rocks with the neighbouring flagstones, the only place where they are visibly in contact at Brough being along the line of fault above referred to. As the rocks of Dunnet Head are evidently a continuation southwards of those of Hoy on the opposite side of the Pentland Firth, where the red and yellow sandstones have been shown by Sir Archibald Geikie to rest unconformably upon the denuded edges of the flagstones, there can be no doubt that the effect of the Brough Fault is to throw the Dunnet Head sandstone on the west against the flagstone series. No undoubted fossil evidence has yet been obtained to fix the age of these beds; only a few obscure plant-like markings resembling rootlets were found last season. The strata on the headland form a gentle syncline, favourable to the production of the magnificent cliffs by which it is almost surrounded, only breached at intervals by narrow trenches or "Geos," where the decomposing dykes and fault lines pass out to sea.

Newer Igneous Rocks.

Findhorn and Carrbridge Area.—The mass of newer granite referred to in last year's Report (p. 82), has been traced southwards across the moor on the west side of the Findhorn, from Allt na Frithe to the Kyllachie Burn. Over part of this distance, as, for instance, between Carn na Seannachoille and Beinn Bhreac, the intrusive mass, largely covered with peat, is about half-a-mile in breadth, but southwards, in the Kyllachie Burn, it forms a rocky gorge over a mile in length. Throughout this belt, the flesh-coloured variety, with quartz, orthoclase, and biotite predominates. The porphyritic type, with large phenocrysts of orthoclase, some four inches across, is conspicuously developed at the head of the rocky gorge in the Kyllachie Burn, Dr. Horne.

Dr. Horne. about three miles west of the Findhorn. Northward, however, by Beinn Bhreac, the rock is less markedly porphyritic, and becomes uniform in grain where it is associated with numerous thin lenticles and knots of acid gneiss.

Another tongue or branch of the Moy granite mass has been traced along the bottom of the Findhorn valley, from the railway cutting at Drumbain southwards to near Clune. It is exposed on the east bank of the river opposite the Dell of Morile, in the lower part of the Press Burn, and in the Findhorn, near the mouth of that stream. This represents the basic modification of the plutonic mass, being non-porphyritic, with abundant plagioclase and biotite, and some hornblende. It weathers in large spheroidal masses, which are well-displayed on the river bank. An excellent instance of the contact metamorphism produced by this basic intrusion is seen on the east side of the river, about 100 yards below the point where it is joined by the Press Burn. The intermediate type of biotite schist is there converted into a hard rock with numerous white silky needles of sillimanite, the igneous material being exposed in the bed of the river.

Mr. Carruthers. A small boss of unfoliated diorite, seen in the burn about half-a-mile due south of the Slochd Mor, may be referred to the basic phase of the Newer Granite, while the quartz porphyry dykes that pierce the siliceous schists north of the Slochd probably represent the later and more acid portions of the same intrusion.

Mr. Anderson. A large intrusion of the Newer Granite has been met with along the county boundary to the south-east of Carn Sgriob. In probable connection with this igneous mass are the veins of granite and pegmatite with which the metamorphic rocks of the district are abundantly injected; while the schists themselves are coarse in grain, pinkish in colour, and often closely resemble a granite. In many of the veins in the ground to the west of Carn Sgriob the central portion is granite, while the marginal portions show pegmatitic structure.

Two dyke-intrusions of a different character have also been observed in the area, and are described by Dr. Flett as fine-grained non-porphyritic felsites. One of these, a mile north of Carrbridge, has a north-east trend, and shows fluxion structure along its edges.

Dr. Peach and Dr. Crampton. *Caithness.*—A new feature in the geology of Caithness is the presence of what appears to be a volcanic vent or ash neck, piercing the sandstones of Dunnet Head, and, like them, presumably of Upper Old Red Sandstone age.

At about one-third mile north of Brough, where the Burn of Sinnigoe flows into the sea over ledges of sandstone, the stream passes for a distance of about 300 yards through an agglomerate made up mostly of broken sandstone fragments, with a considerable admixture of decomposing slaggy igneous rock débris. The junction of this rock with the sandstones is nowhere visible, but the successive beds seen in the cliffs can be traced inland, striking against this mass of agglomerate, and

as no line of fault is seen to cut the sandstones on the face of the cliff, it may be inferred that the agglomerate mass represents a volcanic vent which pierced the sandstones at or about the time of their partial consolidation. Dr. Peach and Dr. Crampton.

A series of thin dykes with a nearly east and west trend was met with in the areas of flagstones and Dunnet Head sandstones. mapped by Dr. Peach and Dr. Crampton. A specimen submitted to Dr. Flett for examination was named monchiquite, being similar to the monchiquite dykes of the Orkneys, which he has described.

Some of the dykes which pierce the sandstones of Dunnet Head are evidently the continuation eastwards of those previously mapped by Mr. Greenly. These intrusions and the ash neck already referred to may have been connected with the volcanic phase, which, in Scotland, began near the end of Upper Old Red time and was continued far into the Carboniferous period.

PLEISTOCENE AND RECENT.

Loch Monar and Glen Fhiodhaig area.—Further evidence has been accumulated to show that, during what may be regarded as the confluent glacier phase of the glacial period, the drainage basin of Loch Monar and the head waters of the river Farrar was filled with a huge mass of ice which, when at different levels, found relief in several different directions. The highest points of exit yet observed appear to have been over the cols that separate Glen Orrin from the two valleys which fall southwards towards Loch Monar on either side of Meall Dubh na Caoidhe. The morainic deposits that cover the floor and sides of the high pass at the head of Glen Orrin to a height of over 2,000 feet, and the glaciated surfaces with striæ pointing north-east at the head of Coire Dhomhainn, point to the passage of an ice-stream north-eastwards over the watershed into Glen Orrin. The vertical extent of the ice in the Orrin Valley is further indicated by the fine series of lateral moraines referred to in last year's Summary, while the glaciated surfaces seen to the north-east of Loch na Caoidhe show that it was at one time thick enough to override the ridge between that Loch and the head of Ghleann Chorainn. Mr. Hinxman and Dr. Crampton.

Evidence of the main easterly movement of the Monar glacier is afforded by the direction of the numerous striæ observed on the north side of Meall Mor, on the summits of Meallan Buidhe and the Beinn Dubh, and on the northern flanks of Sgurr na Lapaich. Dr. Crampton and Mr. Anderson.

The glaciation in the valley of the Farrar shows that at one time the ice rose to a high enough level to overflow through the narrow gorge at Monar Lodge, and passing along the flanks of Beinn na Muice, was embayed in the hollow between that mountain and Sgurr na Muice on the north. The striæ found in the hollow between Meallan Odhar and Beinn Dubh an Iaruinn show, however, that at a later period the constriction of the main valley below Loch Monar acted as a partial barrier to the ice

Dr. Crampon and Mr. Anderson. which then found an exit through the hollow mentioned above and so through the valley of the Uisge Misgeach into Strath Farrar.

The rock ridge which extends south from the western foot of Beinn na Muice is crossed by several dry valleys, eroded by the river Farrar when the present river gorge was blocked by ice.

Dr. Crampon. The lateral moraines that mark the retreat of the great Monar glacier are conspicuous in several localities, and show that lobes of ice were protruded south-west through the hollow occupied by the Gead Lochs, and north north-west up Strath Mhuilich to the west of the glen. The large terminal moraines to the south-east of Pait mark one of the last phases of its retreat, and are possibly contemporaneous with the moraines of the corrie glaciers next to be noticed.

These corrie glaciers have left ample records of their existence in the larger corries of Sgurr na Lapaich and An Riabhachan.

Mr. Carruthers. Among the most striking of the traces left by the later glaciation in this region are the hanging valleys, produced by the after-deepening of the main valley by glacial erosion. These are conspicuous on either side of Glen Fhiodhaig, on the north side of Glen Orrin above Loch Caoidhe, and in Strathmore. Most of these are very short, some being in fact mere cirques, but the one on the west side of Meall Lunndaidh is a mile in length. A very perfect example of a hanging valley is presented by the upper part of the glen through which the Amhainn Strath Mhuilich flows down to the head of Loch Monar. The portion above Loch Mhuilich, which lies in a rock basin at the mouth of the hanging glen, is for a distance of a mile almost flat. Below the loch the valley descends abruptly to Loch Monar, the fall being nearly 500 feet in less than half a mile.

Dr. Horne. *Findhorn and Carrbridge area.*—Glacial striæ are of rare occurrence in this area but several instances were obtained on the hill tops between the Findhorn and Nairn, indicating the direction of the iceflow before the deposition of the moraines. One example, pointing N.25°W. occurs on the watershed at the head of Allt a' Mharcaich at a height of about 1,800 feet: another on the top of Creag a' Bhealaidh (1,734 feet) trends N.15°W. These coincide with the movement indicated by the striæ in the railway cutting at Slochd Mor where they point N.26°W.

Excellent sections of stiff boulder clay with well striated stones occur in most of the streams draining into the Findhorn from the west. Moraines are splendidly developed on the plateau north of Kyllachie Burn where they form a series of prominent ridges trending E.N.E., which in places rest on an underlying platform of boulder clay.

Several examples of over-flow channels were noted within the area, of which perhaps a typical instance occurs on the hill slope about a mile and a half south-east of Findhorn Bridge. There a dry channel has been cut partly through solid rock, which trends N.N.E. nearly at right angles to the course of the adjacent tributaries of the Findhorn.

Similar marginal glacial phenomena to those described in last year's Summary (p. 86) have been met with in the valley of the Dulnan. Mr. Carruthers.

Very perfect glacial terraces and deep overflow channels are found in the ground to the south and south-east of the Slochd Mor. This great hollow is itself a fine example of an overflow channel, eroded in shattered rock to a depth of 100 feet, and drained a lake lying to the north west, dammed back by the ice of the Findhorn glacier.

The smaller terraces and dry valleys noticed above correspond in level with a series of similar features observed by Mr. Anderson in the area south of Carn Glas and east of the Ault Ruigh Magaig. Mr. Anderson.

Marginal stream courses are also well indicated in the ground east of the Duthil Burn, where many of the streams, instead of taking a natural southward course to the Dulnan, flow eastwards along valleys originally determined by former positions of the margin of the ice sheet.

Large spreads of sand and gravel occur in the valleys of the Duthil and Auchnahannet Burns and were probably laid down in lakes whose waters were held back by ice crossing the mouths of the valleys in question. Fine examples of "crag and tail" are to be observed near Coulnamoel, east of the Duthil Burn, the disposition of the features indicating a northward movement of the ice.

Caithness.—Further evidence was obtained that this part of Caithness had been crossed during the period of maximum glaciation by land ice which travelled in a W.N.W. direction. The striæ, the disposition of the shelly boulder clay and the transport of flagstone debris in that deposit from the lower ground to the east on to the comparatively much higher ground occupied by the red and yellow sandstones of Dunnet Head, all point to this conclusion. The presence of numerous boulders of augen gneiss like that of Inchbæ, Ross-shire, and of Moine schists and garnetiferous muscovite biotite schists resembling rocks of these types in that county, and the distribution of blocks of Old Red Conglomerate like that of the Ord in Caithness strengthen this inference. Although the dark shelly boulder clay is widely distributed it is unusually very thin except in the bottoms of the shallow valleys. In the northern part of the area it is exceptionally thick along the hollow traversed by the burn of Rathen and where a small stream flows into Philip Harbour near Barrogill Castle. Dr. Peach and Dr. Crampton.

In parts of the area there is often a coating of a more stony boulder clay with more locally derived boulders than the underlying shelly clay. At one place near Philip's Mains, a farm about one mile south from Barrogill Castle, there is a series of concentrically arranged drift mounds which may have been produced by a small local ice-cap on the high ground to the south stretching from Rigfa Hill to Hollandmey, after the *mer de glace* had disappeared.

Several small lakes occur upon Dunnet Head. Although

Dr. Peach and Dr. Crampton.

shallow, several of these are undoubted rock basins while others appear to be drift-dammed. St. John's Loch, east of the village of Dunnet, is a small shallow rock basin scooped out of the flagstones and the yellow sandstones.

PEAT.

Dr. Horne.

Findhorn and Carrbridge.—On the plateau north of the Kyllachie Burn there is a thick covering of peat, which in many places is over six feet in depth and shows in certain localities one growth of pine overlaid by sphagnum. The best section is, however, in the railway cutting N.W. of the Slochd Mor, where the peat is about 12 feet deep and rests upon a deposit of boulder clay from 15 to 20 feet thick. Here there are two successive growths of pine with an intervening layer of sphagnum.

Mr. Carruthers.

The plateau between the Findhorn and Dulnan, to the W. and S.W. of Carn Glas, also presents an extensive and almost unbroken area of peat, sometimes as much as 14 feet in depth, and with an average thickness of six feet.

Dr. Peach and Dr. Crampton.

Caithness.—The flagstone areas, especially where there is a coating of boulder clay, are eminently favourable to the growth of peat. Most of the country has been more or less coated with it except where it has been removed for agricultural purposes or for fuel. Considerable tracts, however, are still occupied by deep peat south and east of Dunnet as, for instance, the mosses of Ratter, West Mey, and Hollandmey, Backlass and Slickley. In the east the great peat moss of Kilmunster and Wester has been followed northwards to join the Moss of Quintfall. The northern limits of this great moss have not yet been traced, but it is probably one of the largest in Caithness.

ECONOMICS.

Mr. Anderson.

Carrbridge and Findhorn.—The limestone in the Duthil district was at one time wrought for agricultural purposes, and might still be profitably so used. Peat was formerly used as fuel in the kilns and was said to produce better lime than coal, while it permitted the limestone being burnt in larger blocks. The peat is still in general use throughout the district for domestic purposes.

The limestone in the Findhorn Valley, described by Dr. Horne, was also at one time worked on a small scale.

Dr. Peach and Dr. Crampton.

Caithness.—In the western part of the region second-rate flagstones were formerly extensively quarried and exported from the Hill of Barrack and Inkstack in the Dunnet area; but at present only a little road metal is quarried there. Thin flagstones were also worked at East Mey but the quarrying has been abandoned except for farm purposes. Rough flags are available everywhere and almost every farm and croft has one or more openings from which material for local use, such as farm buildings and dykes, and road metal, is occasionally quarried. Most

of the main roads near Dunnet are metalled from the refuse from Castlehill Flagstone quarries. Dr. Peach and Dr. Crampton.

A practically inexhaustible supply of excellent building stone might be obtained on Dunnet Head. The red and yellow sandstones of the headland yield stones of all sizes particularly suitable for dock-building or any similar massive structure. At present only a few stones are quarried to supply a very restricted demand for lintels and gate posts, but formerly the material seems to have been much used for millstones.

The boulder clay might serve for making rough bricks, while the blown sand of Dunnet Links might supply material for plaster and concrete. It might even be profitable to cart it into the interior to spread over the peaty and clayey areas, as excellent crops grow where the blown sand is encroaching over the peat, alluvium and clay soils.

In the eastern area, only a few small temporary quarries near Quintfall, Hillhead and Keiss were in operation last season for local purposes, including road metal. The flags are inferior to those obtained from the large quarries at Castleton and elsewhere in the county.

3. Glasgow District.

B. N. Peach, LL.D., F.R.S., District Geologist, and after his resignation L. W. Hinxman, B.A.

C. B. Crampton, M.B., C.M.
E. M. Anderson, M.A., B.Sc.
R. G. Carruthers.
} Geologists.

During the progress of the revision of the Glasgow district valuable assistance has been freely rendered to the officers of the Survey by proprietors, coal-masters, directors and managers of fireclay works, mining and civil engineers and many others, to all of whom cordial thanks are due. Mr. Hinxman.

An important modification—foreshadowed in last year's report*—of the existing map (Sheet 31) of the country eastwards from Glasgow to Glenboig is due to the adoption of a different horizon for the upper limit of the Carboniferous Limestone Series. In the original survey the Calmy or Garnkirk Limestone was taken for this purpose, the Castlecary Limestone not having been recognised in the area. The prosecution of the fireclay industry has, however, furnished a mass of underground evidence from which the approximate position of the base of the Roslin Sandstone (Millstone Grit) has been established, and the structure of the ground more or less completely elucidated.

The position of the Castlecary Limestone has been proved in a bore put down at Saughs, 2 miles west of the Fireclay works at Garnkirk In the eastern part of the area the lower fireclays

* Summary of Progress for 1900. p. 101.

Mr. Hinxman.

rest at a constant distance of 2 to 3½ fathoms above a persistent band of cementstone, whose position relative to the Castlecary Limestone has been shown by a series of bores in the Castlecary district. So that although this limestone does not appear in the area around Glenboig, the position of the base of the Sandstone Series can be traced with a fair amount of accuracy. Between Steps and Garnqueen the rocks of this series occupy a wide basin, the thickness of strata in the centre of the syncline at Garnkirk being nearly 400 feet. Between Garnqueen and Glenboig the syncline is succeeded by a flat anticlinal arch of inconsiderable breadth, on the further side of which the beds dip steadily to the east at low angles.

The Garnkirk syncline is cut off both to the north and south by powerful east and west faults, that to the north—the Garnkirk fault—having a downthrow to south of eighty fathoms.

Near Johnston Loch this fault passes entirely into the Carboniferous Limestone Series, and crossing the eastern limb of the anticline three-quarters of a mile N.N.W. of Glenboig, shifts the base of the Roslin Sandstone on the upthrow side from near Inchnock to Castlehill, a distance of nearly a mile. The outcrop is again cut off in the direction of Mollinsburn by another powerful east and west fault, and once more shifted to the east.

The Carboniferous Limestone strata which occupy the ground northwards from the Garnkirk fault to the Luggie Water, are arranged in a similar system of gentle undulations. This type of structure, coupled with the low dip of the beds and the truncation of the folds by successive faults, prevents the outcrop of the Edge Coals, or indeed of any beds much below the Calmy Limestone, over a wide area.

In the Glenboig and Gartverrie district the principal fireclay seams occur on two horizons separated by about 150 feet of strata—principally sandstones, but including over a part of the area a sill of dolerite varying in thickness from nine to twenty-four feet.

The upper fireclays are seen at the bottom of the Gartverrie sandstone quarry, where the section is as follows:—

5. Soft white sandstone with harder bands coarse and gritty at base	25 ft.
4. Dark shales and shaly fireclay	3–12 in.
3. Grey and white fireclay	4–6 ft.
2. Hard calcareous sandstone	4 ft.
1. Fireclay	4–6 ft.

The upper band (3) has been worked opencast in the quarry, the lower seam (1) is mined from the crop, the hard stone (2) forming a good roof for the mine.

The position of the lower fireclays in the Roslin Sandstone (Millstone Grit) sequence is definitely fixed by their relation to the cementstone, locally known as the "Roman Cement" which lies from 40 to 50 feet above the Castlecary Limestone. The distance between the fireclay and the cementstone is fairly

constant, varying from 12 to 18 feet in the Gain and Glenboig areas to 24 feet at Heathfield. The cementstone is exposed in the old quarry at Greenfoot, and is a hard ferruginous dolomite that, further to the west, is believed to pass into a clay ironstone. Mr. Hinxman.

The outcrop of the lower fireclay beneath a dolerite sill can be followed northwards from Glenboig to a point a little to the north of Inchnock, where it is cut off by the Garnkirk fault, to appear again a mile to the eastward above the Greenfoot sandstone quarry.

The sections seen at Greenfoot and Glenboig give the following approximate sequence of beds:—

Dark shales with marine fossils	6–8 ft.
Thin coal	1–3 in.
Dark shaly fireclay with lenticular sandstones	
Fireclay, dark at base	6 ft.
White fireclay	6–7 ft.
Shales and sandstones with nodular Clayband Ironstone	12–18 ft.
Cementstone, sometimes in two seams	1–2¾ ft.
Shales	8 ft.
Soft white sandstone	

The thin coal seam above the fireclay is not always present, but on the other hand appears sometimes to reach a considerable thickness. Near Woodneuk House a coal over 1 foot thick overlies a fireclay which is presumably in the same position.

In the shale above the coal Mr. Tait has detected the scale of a *Rhizodont* fish, *Lingula*, *Productus*, *Orthotetes*, and a gasteropod.

Although the general horizon of the fireclays seems to be maintained over a wide area, the individual bands vary much both in thickness and character. The irregular surface of some of the seams indicate a large amount of local erosion previous to the deposition of the overlying strata. In the Klondyke workings at Glenboig the roof of a 6 feet seam often descends to within a few inches of the pavement, rising again in a short distance to its former level. These swelling protuberances of the sandstone roof are called by the miners "bellies." The lower fireclay was formerly mined along the crop between Glenboig and Inchnock. It is now raised in the Star and Klondyke Pits at Glenboig, and mined on the west side of the Caledonian Railway, 1¼ miles to the N.N.E.

Considerable progress has been made in the revision of the area within the City of Glasgow on the north side of the Clyde, but owing to the extent of ground built over since the last survey, and the consequent cessation of all mining operations, little modification has been made in the lines of coal-crop, underground faulting, etc., on the existing map.

Information derived from bores put down for water and in connection with the main drainage system has, however, enabled

r. Hinxan.

the outcrops of the Index and Calmy Limestones to be modified and traced further through the central part of the City. A provisional base line has also been sketched in for the Coal Measures and for the Roslin Sandstone Series (Millstone Grit). In this connection mention should be made of the help afforded by the observations of Mr. Neilson, made in former years, of sections which are now for the most part no longer visible.*

With a view to determining the position of the palæontological boundary line between the Upper and Lower divisions of the Carboniferous strata, Mr. Tait has searched the quarries in the Roslin Sandstone at Garngad Road and Blochairn, and has obtained from the shales underlying the sandstone at the former locality a series of plants determined by Mr. Kidston to be of lower facies. The horizon lies approximately 125 feet above the Castlecary Limestone. It is worthy of note that a succession of thin coal, shale with marine fossils, and sandstone is found at Garngad, similar to that described as occurring at Glenboig.

r. Crampton.

The area revised by Dr. Crampton in Stirlingshire, between Kilsyth and Kirkintilloch, is chiefly occupied by rocks of the Carboniferons Limestone Series, the strata represented ranging from beds a short distance below the Kilsyth Coking Coal to a horizon between the Calmy and Castlecary Limestones. A considerable part of the area is covered by intrusive igneous rocks in the form of sills and dykes of dolerite.

From the underground information freely placed at the disposal of the Survey by the managers of the principal collieries in the district, the following succession of the coals, limestones, and associated sediments has been established in this area:—

	Fathoms	Thickness.
Calmy Limestone		6–8 ft.
Strata	1–2	
†Shirva or Hirst Coal		3–5 ft.
Strata	2	
Lower Hirst Coal		
Strata	10	
Thin Limestone		
Strata and Thick Sandstone	20	
Thin Limestone		
Strata and Thin Coals	30	
Thin Limestone		
Strata	20	
Strata and Chapel Green Coals	3	
Strata, including 60–80 feet of Sandstone (Bishopbriggs)	33	
Blaes and Balls	3½	
Index Limestone		5–6 ft.
Strata	7	
†Twechar Coals		1 ft. 6 in. to 2 ft.

* "Geological Notes on the Cuttings in the City of Glasgow Union Railway between Belgrove and Springburn." By James Neilson. *Trans. Geol. Soc. of Glasgow*, vol. v., p. 222.

† Worked at the present time

	Fathoms.	Thickness.
Strata	7	
Blackband Ironstone No. I.		
Strata and thin coals	19	
*Main Coal of Wester Gartshore and Meiklehill (Haughrigg Coal of Kilsyth) (Anthracite at Gartshore)		2 ft. 2 in. to 3 ft. 4 in.
Strata	2–3	
*Wee Coal		1 ft. 7 in. to 2 ft. 6 in.
Strata with thin coals and B.B. Ironstone No. 2	20	
Nackerty or House Coal of Neilston		2 ft.
Strata	4	
*Blackband Ironstone No. 3 Haugh and Neilston		
Strata	4–7	
Twechar Wee Coal = Smithy Coal, Neilston		2 ft. 3 in. to 2 ft. 9 in.
Strata	7	
*Cloven Coal, Kilsyth = Soft Coal, Neilston		2 ft. 5 in. to 3 ft.
Strata	20	
Highland Park Seam and Lower Steam Coal, Neilston		1 ft. 5 in.
Strata	5–10	
Black Metals, including the Banton Clayband Ironstones or Logan's Bands = California Claybands	10–15	
Strata	14	
Banton Blackband Ironstone = Lower Garscadden, Ironstone-Strata with Garibaldi Clayband Ironstone	5	
*Garibaldi Coal or Upper Coking, Neilston		1 ft. 6 in.
Strata	7	
*Coking Coal of Kilsyth, Wester Gartshore, Meiklehill, and Banton		3 ft. 6 in. to 4 ft. 3 in.
Strata	2	
Wee or lower Coking Coal		
Strata, largely Sandstones	30	
Banton Smithy and Macgregor's Coal		

Only a few of these coal seams, such as the Main and Main Coking Coals, can be traced over wide areas with any uniformity. Certain positions, however, like those of the Blackband Ironstones, the Black Metals, and Garibaldi Claybands, can be followed with some certainty, and in many cases afford as good an index of position as the Index Limestone itself.

There are usually three and sometimes four thin limestones between the Calmy and Index Limestones. These are not, however, constant in their relative position either to each other or to the thicker seams. In the south-eastern part of the area two thin limestones are locally developed between the

* Worked at the present time.

Dr. Crampton. Index Limestone and the coking coal; while the coals also thin out considerably in this direction.

Careful examination of the mining plans in the Kilsyth district has made it apparent that the structure in the anticline known as "the Riggin" is not so simple as formerly supposed. The coals and associated strata are found to be arranged in a series of more or less parallel wave-like troughs and ridges, having a general N.E.–S.W. trend. Elsewhere the beds undulate at low angles, and are much faulted, causing considerable difficulty in tracing the outcrops.

Dr. Crampton and Mr. Hinxman. The dolerite sills, one of which is at least 100 feet in thickness, are shifted, both in this region and in the ground south of the Luggie Water, by the east and west faults. The dykes on the other hand, which appear to cut the sills, are apparently later than the faulting, and in several cases have been intruded for some distance along these lines of dislocation.

Mr. Anderson. The area surveyed by Mr. Anderson to the S.W. of Glasgow is occupied by strata ranging from the lower limestone group of the Carboniferous Limestone Series up to the Coal Measures.

A large fault with a downthrow to N.E. crosses the area in a N.W. direction. On the S.W. side of this fault only Carboniferous Limestone rocks are met with, but on the downthrow side the succession includes strata between the lower part of the Carboniferous Limestone and the upper seams of the Coal Measures, the beds rising to the N.W. in which direction the fault is diminishing in throw. The strata represented in the area on the S.W. side of the fault range from the Cowglen or Index Limestone to a little above the Arden or Calmy Limestone (No. 5 of Midlothian), the latter being probably about 90 fathoms above the Index in this district.

The sequence between these two horizons appears to be as follows. Forty fathoms above the Cowglen occurs a band of limestone, formerly regarded as the Cowglen but first shown by Captain Stewart of Williamswood to be a separate seam, and provisionally named by him the "Hole-burn" Limestone.*

Between the Holeburn and the Cowglen the succession is variable. In many places a thin band of limestone is proved by bores to occur about 10 fathoms above the latter, associated above and below with sandstones and shales with a few thin coals. A coal is found immediately below the Holeburn Limestone which at Thornliebank, where it was recently worked, is nearly 3 feet thick but of poor quality. In the southern part of the area the interval between these two limestones is almost entirely occupied by sandstones, often gritty in character. The lower part of this sandstone is evidently on the horizon of the Bishopbriggs Sandstone, which overlies the Cowglen to the N. of Glasgow, but its coarse gritty character renders it of less economic value than the Bishopbriggs stone. The Holeburn Limestone is succeeded above by 30 fathoms of strata also

* Notes on the Limestones in the Parishes of Cathcart and Eastwood, Renfrewshire. *Trans. Geol. Soc. of Glasgow*, vol. vii., p. 158.

consisting almost entirely of sandstone, the lower 60 feet of which has been extensively wrought in the well-known Giffnock Quarries. Mr. Anderson.

Above this sandstone follows the thin band of cement limestone formerly worked under the name of the Orchard Cement. It is succeeded by a few fathoms of highly fossiliferous shale.* The further succession upwards to the Arden Limestone has not yet been clearly established.

The recognition of the Holeburn Limestone as a separate band has led to considerable modification of the existing map of this region. Captain Stewart has shown in the paper referred to above that the Orchard and Holeburn seams also occur in the southern part of the area, where they form a basin whose deepest part near Davieland is occupied by the Arden Limestone. Great assistance has been rendered to the Officers of the Survey during the revision of this part of the area by Captain Stewart, who kindly communicated the contents of a large number of bore journals as well as other information. The map accompanying his paper (above referred to) contains the basis of many important alterations which will be embodied in the revised edition of the Sheet.

Calciferous Sandstone.—The lowest known horizon in the Barrhead district is the Hollybush Limestone, which lies about 50 fathoms beneath the Hurlet seams. In the course of the revision of the district the Hollybush Limestone, with an underlying coal, 14 inches thick, has been found to occur over a wide area. It has been recognised in bores at Hillington, at Shieldhall 3½ miles to the N.E., and in the reservoir half a mile S. of Hawkhead House, where it has yielded a large number of fossils, corals being especially plentiful. Mr. Carruthers.

A higher limestone, about 30 fathoms above the Hollybush position, is exposed in the railway cutting at Blackbyres north of Barrhead.

Carboniferous Limestone.—The outcrop of the Hurlet Limestone, now accepted as the base of this series, is thrown westwards from Nether Crookston for a distance of one and a half miles by the east and west fault shown on the present map; and an interesting point in the revision of the region has been the recognition of the Hurlet seam in the area between this fault and the Clyde. Over a great part of this area, as also at Old Crookston on the south side of the fault, a sill of dolerite has been intruded along the horizon of the Hurlet seam, and an admirable section showing the relation of the sedimentary and igneous rocks is exposed in the deep cutting near Arkleston on the Glasgow and Paisley Joint Railway.

The Hurlet Limestone occupies the highest part of the section, having a maximum thickness of 3½ feet, and is underlain by about 6 inches of alum shale, much burnt and pyritised.

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* "Notes on the Fossils of the Orchard Limestone Series." By James Armstrong and John Young, F.G.S. *Trans. Geol. Soc. of Glasgow*, vol. v., p. 250.

Mr. Immediately beneath follow the dolerite and Hurlet Coal. The
Carruthers. latter—originally from 5 to 6 feet thick—has been split up the centre by the intrusion, and now lies both above and below the dolerite sill which is here about 80 feet in thickness. Lenticles of coal also occur within the igneous rock, and the coal wherever seen is much burnt and shows fine columnar structure. Beneath the coal follow 18 feet of shale and fireclay with a band of entomostracan limestone, as at Campsie; but the limestone is here in three seams, and much pyritised.

Similar phenomena are seen at Blackhall, S.E. of Paisley, and at Old Crookston near Hurlet. About 30 fathoms above the Hurlet Limestone comes a series of clayband ironstones, long worked in the Hurlet district and still wrought at the Old Victoria Pit, Nitshill. Here they are called the "Househill" claybands, a name which it is proposed to adopt.

Immediately overlying these, and useful as an index to their position, occurs an entomostracan limestone in several thin bands, seldom exceeding a foot in individual thickness. This limestone has been observed at several localities in the district and has been quarried half a mile west of Blackhall. It is proposed to name this band, which is very constant, and has been proved in every bore in the district which passes through its position, the Blackhall Limestone.

Recent information derived from bores and pit sections in the area north of Crookston has to a large extent explained the structure of that part of the district. The important group of ironstones that lie beneath the gas coal are found to occur over a considerable part of the area, and the outcrop of the Garscadden Blackband is repeated around Cardonald Station by successive step faults, all throwing down to the west.

Possil or Edge Coals.—New evidence has been obtained with regard to these coals, with the result that former correlations shown on the map have been altered to some extent. Thus the Satturland coal of Barrhead and Nitshill has been shown to be identical with the two-feet coal of Cowglen, instead of with the Splint or Gas as formerly supposed. The latter coal lies about 14 fathoms below the two-feet coal, and is the same as the well-known Knightswood gas coal.

Upper Limestones.—The position of the Cowglen or Index Limestone is well known all over the district between Cowglen and Barrhead, through the numerous bores that have been put down to the underlying coals and it is exposed in the new railway cutting immediately south of Barrhead. It is found to be everywhere overlain by a thick sandstone, the equivalent of the Bishopbriggs Sandstone north of Glasgow. This sandstone, whose coarse, pebbly character distinguishes it from the other sandstones of the series, is exposed at many places in the district, especially good sections being seen in the railway cuttings at Nitshill and south of Barrhead. The

Cowglen Limestone is seen immediately beneath this pebbly sandstone at the north-east corner of Waukmill Reservoir and also in the new railway cutting half a mile west of Lyoncross. At the latter locality it is very close to the southern boundary fault, and the evidence suggests that the dislocation of the strata had begun before the deposition of the sandstone. Mr. Carruther

The sandstone is followed, about 30 fathoms above the Cowglen Limestone, by the Lyoncross coal with a cement limestone 14 feet above. Both coal and limestone are seen in the Waukmill Glen, lying upon the pebbly sandstone. To the north of Barrhead the limestone is cut out by a large south-west fault, but the coal still remains and has been worked near Parkhouse, where a bore gives a section down to the Cowglen Limestone which agrees very well with that seen in Waukmill Glen. The Lyoncross coal and limestone appear again, overlying the pebbly sandstone in the Nitshill railway cutting, where in the existing 6-inch map the limestone is referred to as the Orchard Cement. Captain Stewart was the first to suggest * that the limestone in the Nitshill cutting might be the Holeburn seam, which, there is the strongest reason to believe, is identical with the Lyoncross Limestone. About halfway between the Lyoncross and Arden seams lies the Orchard Cement Limestone, which, is shown in numerous bores to occur in two bands, 4 to 5 fathoms apart, in this part of the district. The lowest of these bands is seen in the Waukmill Glen and below it strata representing the Giffnock Sandstone, which has here considerably thinned out, and is no longer of economic value. A generalised section of the Upper Limestone succession, as revised in the Barrhead district, is given below :—

Arden Limestone		10 ft.
Fireclay with impure coal		6–10 ft.
Strata—mostly sandstone		about 23 fms.
Orchard Cement	Top Cement	1 ft.
	Blaes	4–5 fms.
	Bottom Cement	1–2½ ft.
Strata—mostly sandstone with Giffnock Sandstone position		20 fms.
Lyoncross Cement		3–5 ft.
Strata—sandstone and fakes		14 ft.
Lyoncross Coal		1–2½ ft.
Strata—sandstones and fakes, the lower half massive and pebbly (Bishopbriggs Sandstone)		30 fms.
Cowglen or Index Limestone		5–10 ft.

The outcrop of the Arden limestone has not been modified, but the strata above it, coloured as Millstone Grit on the existing map, will now, owing to the change of the base line of that subdivision be included in the Carboniferous Limestone Series.

* *Trans. Geol. Soc. of Glasgow*, vol. vii., p. 158.

ECONOMICS.

Dr. Crampton. The following coal seams are wrought at the present time in the Kilsyth and Kirkintilloch district. The Shirva coal at St. Flanan Pit, as a house coal: the Main and Wee coals at Meikle Hill and Wester Gartshore, chiefly as steam coals: the Kilsyth coking coal, coked at the above collieries: the Twechar, Haughrigg, Cloven, and Coking coals are raised at the Kilsyth and Gartshore Pits, and coked there: the Coking coals are also raised at Neilston and Nethercroy where they are coked. No coals are at present raised in the Carboniferous Limestone area south of the Luggie Water, but shafts are now being sunk to the Edge Coals at Auchengeich and south of Mollinburn.

Coal and coke from the Kilsyth district, and lime from Gorebridge in Midlothian, are used in the treatment of Nickel Ore (Garnierite) at Kirkintilloch. The ore is imported from New Caledonia.

Mr. Anderson. *Coal.*—The Coal Measure area revised in the Strathbungo district south of Glasgow, includes the outcrop of several of the Upper coals—the Mossdale, Rough Ell, Rough Main, Splint Ell, and Splint Main. These seams were all wrought at one time, but no coal is now being raised in this part of the area, though there are collieries working (the Govan and Mount Florida) a short distance further to the east. The ground under consideration is entirely built over, and it is unlikely that mining will ever be resumed.

The remarks contained in the last paragraph apply with still greater force to that part of the city of Glasgow revised north of the Clyde. The Edge Coals were worked up to a comparatively recent date in the area to the west of Shawlands. The seams, which are of no great thickness, include the Rough or Cherry Coal, Geordies Coal, Radical Coal, and the Gas Coal. The last named lies about sixty fathoms below the Index Limestone. It is a gas coal of good quality, and was worked until a few years ago from the Lochinch pit, near Lochinch.

Mr. Carruthers. The Possil or Edge Coals between Cowglen and Barrhead are considered to be too thin for profitable working at the present time. It is probable, however, that they may be again wrought in the future.

Mr. Anderson. The Hurlet Coal, 5 feet 9 inches thick, has been proved at a depth of 213 fathoms in a bore put down at the old Titwood Pit near Crossmyloof, and probably lies (untouched) under a great part of the area.

Mr. Carruthers. *Area South of Glasgow*: *Ironstone.*—In the Barrhead district clayband ironstone is still being raised at the old Victoria Pit by Messrs. Baird. Two seams are worked, the Johnston Clayband, and the Househill band (in three ribs) about sixty-seven fathoms below. The ironstone is calcined at the pit and mixed with the Spanish ore used by this company. The same firm are at the present time sinking a pit to the Nitshill seams at Cooperhill. A large area of clayband ironstone remains to be wrought over this district.

A blackband ironstone, about thirty fathoms below the gas coal, and probably on the horizon of the Lower Garscadden and Banton blackbands, was worked more than twenty years ago near Govan. Mr. Anderson.

The Haugh Blackband Ironstone, twenty-six fathoms below the Meiklehill Main Coal, is now worked at Kilsyth by Messrs. Baird & Co. Dr. Crampton

Cement.

The Lyoncross (cement) limestone is worked at Waukmill Glen. The seam is often as much as 5 feet in thickness but only the lower half is used. When burnt and ground it yields a product of a dark ochreous colour, from the large amount (9·7 per cent.) of iron oxide present. Mr. Carruthers

It is used for fireproof floors, etc., and to a small extent for hydraulic work between tide marks; it sets in three to five minutes. Though cheaper than Portland Cement, it is only half as strong, while its dark colour is an additional drawback. There is, however, a steady, though small, demand for this cement.

The Orchard Cement Limestone, which was wrought for hydraulic lime, is no longer in use. It was classed as a "Roman Cement," containing about 10 per cent. of ferric carbonate in addition to 16 per cent. of silica, and was used for sea walls and "wet" work of all kinds. The cement could be produced at a cost of about £1 per ton, but the industry has been killed by the competition of Portland Cement, which is stronger, and can be produced at the same rate. Mr. Anderson.

Limestone.

The Arden or Calmy Limestone is quarried at Darnley, 1½ miles east of Barrhead, and burnt for building and agricultural purposes. Mr. Carruthers

Building Stone.

The Giffnock quarries extend from Williamwood to near Thornliebank in a belt following the strike of the strata. The largest of them are worked by Messrs. Baird & Stevenson, and by the Giffnock Quarries, Limited. The most valuable part of the stone is a band known as the "Liver Rock," separated by a few feet of blaes from the Hole Burn Limestone. The "Liver Rock" varies from 16 to 30 feet in thickness, and is a fine-grained white freestone with hardly a trace of bedding. In parts it contains carbonates in an appreciable quantity. In the ground to the south of Messrs. Baird & Stevenson's quarries, the sandstone has been extensively mined. The old workings form long galleries separated by thick stoops or pillars, and usually about 30 feet in height. Mr. Anderson

Mr. Anderson. The Liver Rock affords a fine building stone with good weathering qualities. It is also used for monuments, "engine-seats" and grindstones. A coarser sandstone above the Liver Rock is also quarried for building stone. Most of the Giffnock stone is used in Glasgow, but a great deal is also sent to Belfast, while some of the fine Liver Rock has been exported to South Africa and Newfoundland.

Mr. Hinxman. The white sandstones which lie near the base of the Roslin Sandstone, both above and below the fireclays, as well as those found in the Carboniferous Limestone Series between the Castlecary and Calmy Limestones are extensively wrought in the district round Chryston and Glenboig for moulding and furnace sand. The sandstones at the higher horizon are quarried for the same purpose and also to a limited degree for building stone at Blochairn and Garngad, in the suburbs of Glasgow.

Brick Clay.

The brown brick clays of the 100 feet raised beach deposits are used for ordinary bricks on the north side of the Clyde between Parkhead and Dalbeth.

A deposit of blue clay, 35 feet above sea level, is also wrought for bricks and tiles at Williamsburgh near Paisley. The clay is of good quality, but the numerous shells and stones which it contains detract considerably from its value. Boulder clay, sometimes with a small admixture of shale from the neighbouring coal-pit refuse, is used for brickmaking at Robroyston. The included stones are ground up with the clay, only the large boulders being previously removed.

Fireclay.

The fireclays of the Roslin Sandstone Series (Millstone Grit) have within recent years given rise to an important industry, and the output of fireclay products from the Garnkirk and Glenboig district is a large and increasing one.

The fire-bricks produced by the Glenboig Union Fire Clay Company have a wide reputation for their resistant qualities, neither melting nor splitting up under high degrees of heat or sudden changes of temperature. The character of the clay in the district varies greatly in short distances, and skilful selection and careful manipulation are required to secure the best results.

Gas retorts, and furnace bricks and blocks for steel, iron, glass, and chemical furnaces are manufactured on a large scale, and exported to all parts of the world.

From the higher seam of fireclay mined in the Gartverrie Quarry, a white highly siliceous brick has been made. The proportion of alkalies is here somewhat greater than that found in ordinary fireclays, and gives the brick an almost porcelain-like structure, necessitating care in handling.

The Gartverrie clay at the present time is ground for use in furnace work. Mr. Hinxman.

The lower fireclay is also wrought at Garnqueen and Gartliston for furnace bricks and blocks. At the Heathfield and Cardowan Pits, in the Garnkirk area, a large home, and foreign and colonial export trade is done in fireclay products. The articles manufactured include fire bricks and blocks for all kinds of furnaces, coke-ovens, gas retorts, ornamental bricks, vitrified salt-glazed sewer pipes, chimney shafts, etc.

A very siliceous white sandstone, a short distance above the fireclay at Heathfield Pit, is ground and mixed with the clay for the most siliceous products.

A fireclay in the Carboniferous Limestone series and lying immediately beneath the Arden or Calmy Limestone is wrought at Darnley, 1½ miles east of Barrhead, Renfrewshire. The clay, which is of a dark colour, is used for the manufacture of drain-pipes, tiles and firebricks. Mr. Carruthers.

The Calciferous Sandstone strata lying to the north-west of Barrhead are particularly rich in fireclays, and with several new lines of railway traversing the area, offer a favourable field for exploitation.

Paving Stone.

The intrusive dolerite sills in the neighbourhood of Kilsyth are largely quarried for paving setts and cubes, flats for gutters, kerbs, and borders. The refuse from the quarries is used for several purposes. The softer weathered portions of the rock are employed for bottoming roads, while the harder fragments are crushed and sieved in three sizes—blocks 2¼ to 1½ inches for road metal—gravel used for walks and floor concrete, and dust, which is mixed with lime for building cement. The dolerite has also been used for building but is said to carry damp and to be unsuitable for the purpose. The character of the rock varies much in the different quarries, according to the vertical position of the quarry in the sill and also to the thickness of the sill itself, the thinner sills tending to be finer in grain throughout. The difference consists chiefly therefore in texture, the rock from the central portions of the sill being coarser-grained than that from either the top or bottom. Dr. Crampton.

The trade is local, the paving setts going principally to Glasgow, the road metal being supplied to the borough and county councils.

Peat.

The peat at Cardowan Moss, ½-mile south east of the Steps Road Station, is being experimentally dug and dried for moss-litter. The peat, which is from 7 to 14 feet in depth, is brown, and of loose fibrous nature, and therefore suitable for this purpose. Mr. Hinxman.

PLEISTOCENE AND RECENT.

Dr. Crampton and Mr. Hinxman.

With the exception of the higher features formed by the outcrop of the dolerite sills and dykes, almost the whole of the ground revised to the south of the Campsie Hills is swathed in boulder clay. The deposit has been carved by the action of the later ice into a series of well marked "drums," whose longer axes point E.N.E. in the northern part of the area, and a little N. of E. in the ground south of the Luggie Water. The striae seen on the exposed surface of the dolerite also indicate an easterly ice-flow, though nearer to Glasgow cross striae pointing nearly south and due to an earlier movement have been observed.* The drums often present the phenomenon of "crag and tail," the gentle slope facing the east, in the direction of movement.

Roches moutonnées, and marginal channels are found on the summit and flanks of the denuded anticline formed by the dolerite sill on the "Riggin."

The sands and gravels of glacial origin described in last year's Summary (p. 103) have been traced eastwards along the Kelvin valley up to and beyond Kirkintilloch. The sand is of considerable economic value.

The hollows between the boulder clay drums contain patches of peat or peaty alluvial soil that indicate the former position of drift lochans. Some of these, as Hogganfield, Stepps and Johnston Lochs, are still in existence in the southern part of the area.

4. Airdrie District.

Airdrie, Campsie and Kilpatrick Hills, and Charlestown.

Mr. C. T. Clough, M. A. District Geologist.

Mr. J. S. Grant Wilson.
Mr. H. B. Muff, B.A.
Mr. E. B. Bailey, B.A.
Mr. G. W. Grabham, M.A.
} Geologists.

Mr. Clough.

Owing to the completion of Memoir work Mr. Clough did not begin the revision of the Carboniferous rocks in the Airdrie district till near the close of last season. In the course of his work he received valuable assistance from colliery proprietors, managers and mining engineers.

Mr. Wilson was engaged with the preparation of the Memoir of the Oil Shales of the Lothians and was unable to take part in the regular field work in this district, but re-examined some sections of special interest in the oil-shale region.

The resurvey of the Carboniferous rocks in West Lothian during 1904 suggested that the Cobbinshaw Hurlet limestone occupies a lower stratigraphical horizon than the Petershill and

* See also *Summary of Progress* for 1904, p. 102.

Hillhouse limestones, and further, that the Hillhouse limestone probably corresponds with that of Charlestown on the north shore of the Firth of Forth. Formerly the Cobbinshaw Hurlet limestone and the Charlestown limestone were each taken as the base of the Carboniferous Limestone series in their respective localities, but it now appears that they probably occupy different horizons. Mr. Clough

UPPER OLD RED SANDSTONE.

Kilpatrick Hills.—The red and white sandstones (with poorly developed cornstones) which compose Stockie and Quinloch Muirs, west of the Blane Valley, are brought against the volcanic rocks of Calciferous Sandstone age, on the south, by an east and west fault, which has been shown to be continuous with the southern boundary fault of the Campsie Fells. Mr. Grabham.

CARBONIFEROUS ROCKS, INCLUDING THE ASSOCIATED VOLCANIC ROCKS AND ASH NECKS

Calciferous Sandstone and Carboniferous Limestone Series.

Kilpatrick Hills.—No sediments of undoubted Carboniferous age have been mapped, the base of the volcanic rocks in the Calciferous Sandstone Series not being seen within the area. It seems possible, however, that some white conglomeratic sandstones, near the big east and west fault south of Stockie and Quinloch Muirs, may possibly belong to faulted portions of the bed which, at Ballagan, immediately overlies the Cementstone Series.

The lowest lavas mapped form escarpments facing west a little west of Auchineden Hill, which are well shown on the shaded edition of the one-inch map, and it is assumed that the most western of these is very nearly, if not actually, the lowest member of the series, as the rocks which lie further west are obscured by drift, and are probably therefore of a soft character.

The individual flows seem to interdigitate and cannot be traced far, but a general order of succession can nevertheless be established. The four lowest lavas are non-porphyritic olivine-basalts, and these are followed by a series of flows which are nearly all porphyritic. The sequence is thus considerably different from that found by Mr. Bailey in the Campsie Fells, where there is a much larger group of non-porphyritic flows at the base. The porphyritic flows vary among themselves, but the higher beds generally appear to be more basic than the lower, owing to a greater development of porphyritic augite and olivine and a decrease of porphyritic felspar, until about Black Loch and Boards we find thoroughly basic rocks of the Craiglockhart type.* Above these again comes another group of lavas with porphyritic felspar which are well seen west of

* Sir A. Geikie, "Ancient Volcanoes of Great Britain," vol. i. p. 418.

Mr. Grabham. Craigton and south of Strathblane. The porphyritic types agree petrographically with those already described by Dr. Hatch,* for we have rocks similar to those from Markle Quarry, Hailes Castle and Kippie Law.

Zeolites occur frequently, the most characteristic being red stilbite, which has been obtained in large masses in several places, analcime, and acicular crystals of the natrolite-Thomsonite group.

At the northern ends of the two lowest lavas near Auchineden Hill there are bosses which appear to represent small necks partly composed of ash.

Mr. Bailey. *Campsie Fells.*—In last year's *Summary of Progress*, pp. 98 and 99, Mr. Bailey expressed the view that a continuous fissure-like neck constitutes the northern front of the Campsie Fells from near Dumgoyne to Fintry, a distance of four and a half miles, but it has now been found necessary to modify this view considerably. The northern limit of the hills is indeed characterised by numerous intrusions and by necks filled with agglomerate, but the greatest length that can be ascribed to any one neck is somewhat under two miles, and the views of Dr. Jack, who first mapped this area, have been confirmed as regards the interbedded character of the Fintry ashes.

A porphyritic basalt, which perhaps represents a lava flow, is at one place found below the basal tuff of the volcanic series; but with this possible exception, the lower lavas retain a non-porphyritic or sparingly porphyritic character throughout the whole of the eastern part of the area.† At Campsie Glen, where an accurate estimate can be formed of the number of flows in the lower group, as many as 17 were counted underlying the lowest porphyritic lava. The upper group, that which is characterised by the occurrence of strikingly porphyritic basalts, also contains a few non-porphyritic flows.

Mr. Wilson. *South Queensferry area.*—The coast section near South Queensferry was mapped on the 25-inch scale, and two seams of thick and rich oil-shale were found, lying below the Burdiehouse limestone, at depths thereunder of 88 feet and 268 feet respectively. The lower seam may possibly be in the position of the Pumpherston Oil Shale, but this point will shortly be proved by boring operations which are now being carried on at Society by the Oakbank Oil Company.

Mr. Muff. *Charlestown Area.*—The Calciferous Sandstone Series is exposed on the shore between Inverkeithing and Limekilns, on the north side of the Firth of Forth, but the succession is rendered obscure by numerous small faults and folds and by the recent mud of the Forth, which hides many of the softer beds. An important fault, marked by great disturbance of the rocks, runs across the shore from near Rosyth Farm in a west-south-westerly direction, and is probably the continuation of the great

* "The Lower Carboniferous Volcanic Rocks of East Lothian," *Trans. Roy. Soc. Edin.*, vol. xxxvii, p. 115.

† The succession is in fact analogous to that of Arthur's Seat, Edinburgh.

dislocation which runs from Little Couston, near Aberdour, to the plain north of Inverkeithing. On the south-south-east side of the fault, the beds are thrown into a gentle anticline and affected by small faults and local folds. The centre of the arch is marked by the basalt on which Rosyth Castle stands, on either side of which is a thick series of grey and white sandstones, which were formerly quarried. Some distance above these sandstones is a bed of very pale limestone of the Burdiehouse type, about six feet thick, which is underlain by a dark bituminous shale full of entomostracan remains and associated with thin bands of dark limestone. This series is exposed on the shore at low tide near the new Admiralty offices, and again to the S.S.W. of Rosyth Farm. To the S.S.E. of the latter locality is a shallow basin of black shales interbedded with a thin limestone, which is full of *Naiadites*, and probably underlies the pale limestone. The position of the limestone with reference to the oil-shales is still a matter of doubt. Mr. Muff.

On the north-north-west side of the big fault mentioned above, the lower limestones of the Carboniferous Limestone Series and beds high up in the Calciferous Sandstone Series are exposed. The oil-shales of the Lothians probably occur at some depth, but are nowhere known at the surface. Immediately north of the fault, dark blaes with a thin cementstone occur, and on the flanks of an anticline in the bay east of Rosyth Church, a cementstone band, containing gasteropods, appears on the same horizon. The cementstone is overlaid by blaes, with ironstone ribs, and sandstones and shales, followed by a yellowish, sometimes quartzose limestone, which is exposed in the cliff of the raised beach on the golf course and again at the point east of Rosyth Church, being thrown down to the latter position by a N.W.-S.E. fault. After crossing over a series of sandstones and shales, estimated to be not more than 150 feet thick, we reach the lowest band of marine limestone—a dark encrinital rock—which is exposed on the shore below Charlestown railway station and again opposite the school at Limekilns. The section at the former locality has been proved by excavation to be as given below—

	Ft.	In.
Blaes		
Dark encrinital limestone - - - - - - - -	4	–
Dark blaes with fossils - - - - - - - -	4	6
Coal, with pyritous band - - - - - - - -	–	10
Fireclay		

A similar section is exposed in the low cliff a quarter of a mile W. of Rosyth Farm. Mr. Tait has found that the shales beneath the limestones in these two sections contain a similar set of fossils. The crop of the limestone near Rosyth Farm cannot be followed far, for along the strike we find bituminous blaes with the thin cementstone band already referred to. There can be little doubt that the former limestone is let down by a fault trending N.W.-S.E., and that it is the same band as that at Charlestown railway station.

Muff. The limestone which overlies the dark shale, coal, and fireclay in the old fireclay mine at Sunnybank, one mile north of Inverkeithing, is probably another exposure of the same band.

The thick "Charlestown" limestone, so extensively wrought at that locality, and formerly taken as the base of the Carboniferous Limestone Series, lies about 150 feet above the limestone already referred to at the railway station. It rests on a bed of shale, a foot or two thick, overlying a 2-feet bed of encrinital limestone, and is distinguished from the other limestones of this district by its greater thickness, the presence of cherts, and the abundance of *Productus giganteus*. In all probability it is the same as the Petershill Limestone of the Bathgate Hills, and the limestone at the railway station may therefore represent the West Kirkton limestone of the same district. In a little syncline, exposed in the railway cutting three-quarters of a mile west of Charlestown station, a thin limestone occurs which lies about 180 feet above the Charlestown limestone. The following section is shown in the cutting:—

Coarse tuff	
Dark limestone - - - - -	2 ft. to 2 ft. 6 in.
Sandstone - - - - - -	2 ft.
Shale - - - - - - -	2 ft.
Coal - - - - - - -	1 ft.
Fireclay and blaes - - - -	6 ft.

This succession is very like that on the coast a quarter of a mile east of the foot of Carriden Glen, Bo'ness: hence it seems probable that the limestone in the Charlestown railway cutting represents the Lower Carriden Limestone of West Lothian.

An exposure of ash near low tide-mark in Ironmill Bay may represent an ash neck, and, in addition to this, there are other representatives of the volcanic rocks of the Bathgate Hills, namely, the tuff overlying the limestone in the railway cutting and several beds of green tuff interstratified with sandstones in the middle of Ironmill Bay.

Excepting a small isolated crop of limestone near the tuffs mentioned above, the next limestones met with are the three bands at Kinning Point, the lowest of which is about two feet thick, with shale and a thin seam of coal beneath it, and is easily distinguished by its layers of *Lithostrotion irregulare*. Above it come blaes containing ironstone nodules which were wrought formerly along their outcrop, and then a calcareous sandstone which contains occasional patches of tuff and exhibits a curious curved bedding. The Middle Kinning limestone, from six to eight feet thick and about 25 feet above the lower band, is charged with encrinites. It has been recognised inland above Brucefield House, E.S.E. of Dunfermline; in the Lyne burn below Touch Bleachfield, and in the stream north of Baltrougie (1½ miles N.N.E. of Inverkeithing). The upper Kinning limestone is very hard, varies from one to two feet in thickness, and lies immediately on a bed of gannister about 80 feet above the middle band. Inland it has been recognised in the ravine of Pittencrieff Park,

Dunfermline, in the burn above Touch Mill and in the burn below Baltrougie. Mr. Tait found that it is characterised by numbers of *Bellerophon*, so that it is probably the same as the top Hosies limestone described by Dr. Crampton and Mr. Carruthers in the Glasgow district (*Summary of Progress* for 1904, p. 100). Mr. Muff.

COAL MEASURES.

Airdrie Area.—Rock exposures are somewhat rare in the small area revised, but many of the coal seams have been worked up to the cover of boulder clay which spreads over a large part of the district, and therefore it is often possible to map the outcrops accurately. The pits now working in the area are shallow and small, being chiefly engaged in working thin seams which were formerly neglected, such as the Upper Drumgray, worked in No. 8 Pit, Kippsbyre and in Thrashbush and Laverock Knowe Pits; the Virtuewell, worked in Victoria Pit (Airdrie) and No. 6 Pit, Kippsbyre; and the Virgin, worked in the Kippsbyre Incline. The Splint coal is also being worked in the Kippsbyre Incline, and the Kiltongue in No. 8 Pit, Kippsbyre. In parts of the last mentioned pit both the Kiltongue and the Upper Drumgray seams are burnt by thin sills of white trap ("white horse"), and cannot be profitably worked. The roof of the Upper Drumgray is a rather hard black blaes (locally called "blacks") about eight inches thick, which is crowded with remains of *Carbonicola robusta*, but it is important to note that in the two neighbouring pits of Thrashbush and Laverock Knowe—at distances of three-quarters of a mile and a mile and a half respectively—no such remains could be found in this position, though the lithological character of the roof is much the same. Mr. George Black, the manager of Kippsbyre Colliery, states that about nine feet above the Upper Drumgray seam there is another somewhat similar band of blaes with shell remains in even greater profusion, but this band is not now exposed. Mr. Cloug

In an "ingoing eye" into the Kiltongue coal about 330 yards slightly west of south of Pinwinnie, several crush-planes are exposed inclining at low angles—often less than 15°—in a direction about 15° south of east, while the beds traversed are in most places nearly horizontal. Near the top of the section a seam of a bright, somewhat burnt coal—probably the upper part of the Kiltongue—contains a thin impure parting which has been bent into a series of small sharp folds with axial planes inclining easterly, and it seems probable that the crush-planes and the folds have both been developed under the influence of pressure exerted from the east.

In that part of the town of Airdrie which lies on the north side of the big east and west fault, with downthrow to the north generally estimated at 100 fathoms, there is a seam of coal, reported to be very variable in thickness, which appears to occupy the position of the Upper Coal of Glasgow. It is said to have been formerly exposed near the foot of Hallcraig Street

Mr. Clough. and, more recently, in the foundations for an extension of the Public Hall. A coal apparently in much the same position was also met with further west in various pits near the race course, where it was called the "Wandering Coal." Mr. James McCreath, C.E., states that this coal was found to have an average thickness of three or four feet, and to lie about 25 fathoms above the Ell Coal.

It will be necessary to alter the line formerly taken as the base of the Coal Measures near Haggmuir, about two miles north of Coatbridge, but the amount of alteration is still uncertain. A thin coal about 21 inches in thickness, generally known as the Balmoral seam, and directly overlaid by an impure oil-shale, about 28 inches thick, is said to have been pierced in a shallow pit on the west side of the bend of the road about half a mile south of Haggmuir. In the little burn east of the road, a band of dark shale and ironstone is exposed, dipping south about 10°, in a position about 80 or 100 feet below the Balmoral seam. The ironstone, which contains remains of *Carbonicola*, is probably in the position of one of the slaty-band ironstones at the base of the Coal Measures of other districts. A little further west, a bore —No. 1. Haggmuir *—has been put down to a depth of 34 fathoms without meeting any sedimentary rocks except sandstone, faikes, and fireclay, so that it seems probable that the bore starts in beds below the Coal Measures, and that the base of these measures passes between this bore and the shaft referred to, and strikes in this locality nearly east and west.

INTRUSIVE SHEETS AND DYKES.

Mr. Grabham. *Kilpatrick Hills.*—The rock forming the little hill called the "Whangie," near the northern ends of the third and fourth lavas (counting from the bottom) west of Auchineden Hill, seems of intrusive character, and several other intrusions have been mapped further east, along the course of the big east and west fault. The hill of Dungoyach, which is shown as an ash neck in the published map, has been found to be entirely composed of a basaltic intrusion, which is so broken by faults and slickensides that it appears like a breccia in parts.

A good many dykes, composed of olivine basalt and dolerite, and often porphyritic, intersect the Old Red Sandstone north of the lavas, but none has been noticed in the lavas themselves.

Mr. Bailey. *The Campsie Fells.*—The main basaltic intrusions of the hills are fine in texture and frequently markedly columnar. Microscopically they are similar in character to the non-porphyritic lavas, but as a rule much fresher.

A big intrusive sill of trachyte, of the same type as that of Traprain Law, is well exposed in a quarry in the wood at Newton, Fintry, where it is intersected by at least two dykes of basic character.

* The Journal of this Bore was kindly given by Mr. Harry Lewin, C.E.

Airdrie Area.—Intrusive sills of dolerite are somewhat common in the Coal Measures and are found on various horizons, extending from a little below the Lower Drumgray coal to a little above the Virtuewell. In the North Burn—on the north side of Airdrie—there are also two sheets a little below the Ell Coal. None of these sills is known to exceed 45 feet in thickness, and none appears to contain any pink micropegmatite veins and spots such as often occur in the thicker sills in the Midland Valley of Scotland.* Various coal seams have been considerably "burnt" near these intrusive sheets. Mr. Clough

In the Kippsbyre Pit No. 8, the thin irregular sills of white trap, which sometimes occur on the horizons of the Upper Drumgray and Kiltongue coals, can be inspected underground for considerable distances, the roof and pavement of the seams being distinctly traceable. It is stated that the presence of the sills always increases the vertical distances between the roof and pavement, but by a less amount than their own thickness; the sills are often from six inches to four feet thick, and at any particular spot the increase in the distances referred to is, perhaps, only a third of the thickness at that spot. In this pit an underground road is now being driven horizontally along the position of the Upper Drumgray seam, in order to reach a part of the field in which the coal has been proved by boring to be in a sound unburnt condition; it is stated that the road has now been driven for a distance of 27 yards with the roof and pavement of the coal in sight the whole distance, but without any coal between them.

At the east end of the Thrashbush whinstone quarry† the Virtuewell coal is exposed immediately below the sill. Coal is also seen just above the sill, and it appears probable that the sill, which is here about ten feet thick, has split up the seam near the middle without diminishing its thickness.

PLEISTOCENE AND RECENT.

Kilpatrick Hills.—Various additional glacial striæ have been noticed with directions similar to those already shown on the old edition of the published map. Mr. Grabham

Boulder clay covers some of the longer dip slopes and often fills the hollows between the lava escarpments, but it is frequently covered by a growth of peat.

The broad stretch of sand forming the bottom of the Blane Valley north-west of Duntreath Castle, is probably part of the 100-feet raised beach.

Airdrie Area.—The glacial deposits are chiefly represented by a dark grey boulder clay, which sometimes forms drums or ridges striking slightly north of east. In an air shaft lately sunk about 700 yards slightly north of east of Airdrie House a thickness of 84 feet of such clay has been proved. Mr. Clough

* See, for instance, Mr. Grabham's account of the sills near Linlithgow, in the *Summary of Progress* for 1904, p. 117.

† About a quarter of a mile W.S.W. of the house called Thrashbush.

Clough. Many glacial striæ, trending between 15° and 20° north of east have been observed on rock surfaces recently bared in quarries of whinstone and sandstone.

In the mining plans of the area east of the Victoria Pit, Airdrie, the crop of the Virtuewell seam is in one place drawn N.N.E. for 200 yards or more, in a direction almost at right angles to the usual strike in the neighbourhood. The ground surface is approximately level and it seems possible that the seam outcrops at the side of some pre-glacial hollow which is filled up with boulder clay.

ECONOMICS.

Messrs. iley and abham. *Campsie and Kilpatrick, Hills*—The land is chiefly used for sheep and cattle farming.

The Upper Old Red Sandstone on the northern sides of the hills supplies the local demand for building stone, but there is no important quarry within the area examined.

The igneous rocks, especially the intrusive basalts, provide material for the building of "dry stone dykes," and an abundant supply of road metal. The trachyte sill near Fintry is largely quarried for metal for the roads of the low-lying districts of Strathendrick and those further north. The more hilly roads are supplied partly from local quarries and partly from a series of small pits in the boulder clay.

Mr. Clough. *Airdrie Area.*—Though most of the coal seams in the area examined have been exhausted and even small specimens of the once famous Airdrie Blackband ironstone are difficult to obtain, yet the towns of Airdrie and Coatbridge remain the centres of an active and industrial population, increasing in numbers year by year. The blast furnaces smelt ores brought in from a distance, mostly from abroad. Many of the old coal workings are under water, which is now in some cases pumped up for supplying boilers.

The deep Gartsherrie boring, made a few years ago by Messrs. James Nimmo and Co., in ground a little west of the area under description, started in the Coal Measures and went down 313¾ fms. into beds a little below the Kilsyth coking coal. This seam was pierced at a depth of 305½ fms. but it was only 15 inches thick, and the thickest coal recorded in the Carboniferous Limestone Series in this bore is only 23 inches.*

In the district north and north-east of Airdrie many whinstone quarries have been opened out in intrusive sills of dolerite, which supply a large quantity of setts and kerbs as well as small broken material for road metal. The setts and kerbs are occasionally shipped to England from the Clyde, but for the most part they are used in neighbouring towns in the west of Scotland. At the Brackenhirst quarry there is a considerable "cover"—partly of

* J. S. Dixon, "Final Report of the Royal Commission on Coal Supplies," Part vii., p. 4, 1905. R. W. Dron, "The Coal-fields of Scotland," pp. 351–360.

blaes and partly of boulder clay—and a brick-making plant is being erected to utilise this "bye-product." Mr. Cloug

Several freestone quarries—chiefly in beds above the Kiltongue and Virtuewell seams—were wrought a few years ago, but have now stopped, apparently in consequence of the increasing thickness of boulder clay above the working faces.

At the Airdriehouse brick works, common bricks are made by firing a mixture of blaes, procured from an adjacent waste heap, and of boulder clay, dug from an adjoining open work.

Most of the area possesses a stiff cold boulder clay soil, and a large proportion is under pasture.

II. PALÆONTOLOGICAL WORK.

The Palæontological Department in Scotland has been carried on under the general charge of Dr. Peach, Acting Palæontologist, till his retirement, and by Messrs. Crampton and Carruthers, assisted by Messrs. Macconochie and Tait, while the following specialists, Dr. R. H. Traquair, Dr. Wheelton Hind, and Mr. R. Kidston, have, as formerly, rendered valuable assistance. Dr. A. H. Foord, of Dublin, has also determined some Carboniferous Cephalopoda and kindly furnished notes regarding them. Dr. Crampton

The number of fossils collected during the year and entered in the Survey list books amounts to 1,684. The most of these are from Carboniferous rocks, the others being from the Old Red Sandstone of Ross-shire and the *Olenellus* zone of the Cambrian system near Inchnadamff, Sutherlandshire. Some of these fossils have yet to be determined, but most have been reported on by specialists or have undergone preliminary examination.

Dr. Crampton was engaged in revising the nomenclature of the list of Brachiopoda for the Memoir of Sheet 32 (Edinburgh) and Mr. Carruthers was employed in the beginning of the year in examining the Carboniferous corals for zonal purposes. As a preliminary study of the corals by Mr. Carruthers, the morphology of some of the smaller simple forms was carefully investigated by means of a series of transverse sections. The genera *Zaphrentis* and *Lophophyllum* were chiefly selected as they afforded the most perfect specimens. Special attention was paid to the youngest stages of these corals and to the relations of the different septa. As these investigations are incomplete, no definite statement of results can yet be presented. Opportunity was also taken to revise the nomenclature of the corals in the fossil lists of Sheets 32 and 33, in all the specimens available.

A collection of fish remains and plants, numbering 72 specimens, was made by Mr. Tait from the Old Red Sandstone near Edderton, Ross-shire. The plants are not yet determined. The fishes were submitted to Dr. Traquair who reports on them as follows;—

Dr. aquair. "I have examined the fishes collected by Mr. Tait from the grey limestone nodules of the fish beds of the Orcadian series near Edderton in Ross-shire, and find them to be the following:—

Diplacanthus striatus, *Agassiz*
Cheiracanthus Murchisoni, *Agassiz*
Pterichthys productus, *Agassiz*
Coccosteus decipiens, *Agassiz*
Diplopterus Agassizii, *Traill*
Gyroptychius microlepidotus, *Agassiz*
Cheirolepis Trailli, *Agassiz*

All these species occur in the fish beds of the other well-known Middle Old Red Sandstone localities in the Moray Firth area, as at Clune, Lethen, Tynet, Gamrie, and Cromarty. It has already been noted by Hugh Miller that different fishes are more abundant than others in the different localities; in the case of Edderton the most common forms are *Coccosteus decipiens* and *Cheiracanthus Murchisoni.*"

Dr. ampton. Early in the year Mr. Macconochie discovered a fish bed in the Burdiehouse Burn, Midlothian, which has proved a valuable horizon, and was subsequently traced southwards to Bilston Burn and Carlops. This band is probably about the position of the Lower Abden limestone in Fife. Dr. Traquair gives the following report on the fishes from this bed:—

Dr. aquair. "The fish remains collected by Mr. Macconochie from a thin band exposed in the Burdiehouse Burn at Hyvot's Mill are as follows:—

Pleuroplax sp. (teeth and spines).
Oracanthus armigerus, *Traq.* (teeth).
Acanthodes sp. (spines).
Sphenacanthus sp. (tooth).
Megalichthys sp. (scales).
Rhizodopsis sp. (scales).
Strepsodus striatulus, *Traq.* (tooth).
Acrolepis Hopkinsi, *McCoy* (scales).
Eurynotus crenatus, *Agassiz* (scales).

"This deposit is of interest from its resemblance, both lithological and palæontological, to the well-known 'Bone Bed' seen on the shore at Abden near Kinghorn. It is full of broken shells of *Lingula squamiformis*, and the fish remains, though fewer as to the number of species, belong to the same assemblage as those of the Abden Bed."

Dr. ampton. While collecting from the oil-shale group in the river Esk near Carlops, Mr. Macconochie discovered a black seam in an oil-shale charged with Crustacea, which were examined by Dr. Peach and determined as follows:—

Palæocrangon eskdalensis, *Peach*
Palæocrangon elegans, *Peach*
Anthrapalæmon sp.

forms described and figured by him in 1880 from the "fossil scorpion bed" of Eskdale in Dumfriesshire. Some beautifully preserved Crustacea, determined by Dr. Peach as *Anthrapalæmon Etheridgei*, Peach, were also collected by Mr. Macconochie from an oil-shale horizon on the shore north of Gullane, East Lothian. Dr. Cramton.

From a marine bed in the Calciferous Sandstone Series of Fife, Sheet 32, Mr. Tait has brought to light an interesting collection of cephalopods and lamellibranchs, accompanied by species of *Bellerophon* and *Pleurotomaria* and other fossils not yet thoroughly investigated. An exhaustive search was made, and the cephalopods obtained were submitted to Dr. A. H. Foord and the lamellibranchs to Dr. Wheelton Hind. The former specialist has furnished the following report:—

"The fossils submitted to me for examination, though consisting of very few species, are interesting, as almost all carefully collected specimens prove to be. This is especially the case with the series of specimens representing *Glyphioceras truncatum*, Phil. sp., which is very complete, individuals ranging in size from a diameter of 6 mm. to one of nearly 50 mm. with many of intermediate size, being contained in it. Many of the goniatites are in a very young stage of development, so that their specific identity is very difficult to determine. The development of the suture line has yet to be marked out in the great majority of the species of goniatites described; when this has been done the task of identification will be greatly lightened. When the material is abundant the embryonic (or at least very young) shell may be reached by the simple process of breaking back an adult shell, by which means the young shell is exposed inside, and if, by good fortune, the latter is suitably preserved, that is, calcified, we are in a position to determine the nature of the suture line at different stages of growth, thereby throwing light upon the development of the species and also upon its place in the classification of the group." Dr. Foord

NAUTILOIDEA.

Orthoceras cylindraceum, Flem.

Some well preserved though imperfect specimens of this species occur. The slow rate of tapering and very numerous undulating septa make the species easily recognisable.

Orthoceras pyramidale ? Flem.

A fragment more than half buried in the matrix is referred with some doubt to this species, as its rate of tapering cannot be ascertained; but the considerable distance of the septa from each other is a distinguishing feature and lends strength to the probability that the suggestion here given as to its affinities is correct,

Orthoceras sulcatum, Flem.

r. Foord. Several fragments of this species are represented in the collection. The ornamentation, consisting of undulating, transverse costæ, the latter, with their interspaces, covered with fine, transverse, thread-like lines, is well preserved in some of the specimens and puts the identification of the species beyond all doubt.

Actinoceras Sowerbyi, McCoy sp.

A fragment, imperfect at both ends, is clearly referable to this species as it exhibits all the characters necessary for its identification. These may be briefly described as follows:— Shell straight, compressed, ovate in cross-section. Rate of tapering about 1 in 5. . . . Septa, ten of which are seen on the cast, very approximate, distant from each other about 3 mm., very obliquely inclined on the sides of the shell, and forming a sharp angle at the narrower extremity of the ovate outline, where there is a distinct ridge. . . . Test slightly exceeding 1 mm. in thickness.

This species was first figured by J. Sowerby from a specimen obtained from the Carboniferous rocks at Closeburn, Dumfriesshire. The type here referred to is in the British Museum (Nat. Hist.). It is interesting to find it in another locality in Scotland.

Cœlonautilus planotergatus, McCoy sp.

A fragment belonging to this species has an acute keel at the borders of the peripheral area; a feature which I have not remarked in any other specimens of *C. planotergatus* that I have met with hitherto; it may be varietal.

Stroboceras sulcatum, J. de C. Sow. sp.

A small crushed specimen is doubtfully referred to this species.

Coloceras coyanum, d'Orb. sp.

Two small and evidently young specimens represent this species in the collection and exhibit its characteristic features very completely. The smaller one has a portion of the margin of the aperture preserved, posterior to which is a shallow depression or constriction which arches forward on the inflated sides of the shell, and makes a distinct linguiform sinus in the median line of the peripheral area, thus indicating the exact form of the aperture. The sharp keel characteristic of this species borders the umbilical cavity. In the adult shell this keel disappears towards the aperture. Owing to the almost complete absence of the test the septa are well exposed on the cast in both specimens, and as they are not seen in the single specimen upon

which the species was founded by McCoy, I take this opportunity of describing them:—In the larger shell, (T. 1,500 B.) where the transverse diameter of the shell measures 25 mm. the suture lines are 5·5 mm. apart in the median line of the peripheral area, and this interval is maintained throughout the five septa which precede the base of the body-chamber. The suture lines take a nearly straight course over the sides and peripheral area. In the smaller specimen (T. 1,479 B.) the septa are imperfectly visible owing to fracture of the specimen and to their being for the great part concealed under the matrix. About seven of the suture lines are exposed upon the umbilical area, and upon a portion of the lateral area contiguous to it; these represent the last septa formed by this individual before the base of the body-chamber was attained. They are crowded together in the manner so often observed, under similar conditions, in the coiled nautiloids. Their distance apart is scarcely 1 mm. where the transverse diameter of the whorl measures 15 mm. Those seen in the earlier portion of the whorl are 1·5 mm. apart. The greatest diameter of this specimen is 28 mm., that of the larger one, described above (approximately) 33 mm. The siphuncle is not seen. The fragments of the test preserved are quite smooth. Dr. Foord.

AMMONOIDEA.

Glyphioceras micronotum, Phil. sp.

This species is represented by several specimens in different stages of growth and varying in diameter from 12 mm. to 20 mm. The ornamentation, consisting of very fine striae, is well preserved in most of the specimens determined All show the shallow periodic constrictions characteristic of the species.

Glyphioceras truncatum, Phil. sp.

There is an interesting collection of individuals of this species in which the umbilicus is closed, or nearly closed, instead of being open, though very small, as in the English and Irish shells assigned to this species. Numerous specimens occur in different stages of growth. The largest measures nearly 50 mm. in diameter, the smallest about 6 mm. They are mostly well preserved, except for the absence of the test. The smallest individual shows the suture lines with admirable clearness, this specimen being completely calcified and thus in the most favourable condition of preservation.

Glyphioceras subtruncatum, Foord

The specimens referred to this species exhibit the characteristic sigmoidal lines of growth upon the surface of the test, some of them showing also a faint spiral ridge at the peripheral border. All are crushed fragments embedded in the shale."

Dr. Crampton. Dr. Wheelton Hind has named the following species of lamellibranchs from the same bed :—

Edmondia cf. scalaris, *McCoy*
Sanguinolites cf. variabilis, *McCoy* sp.
„ cf. v-scriptus, *Hind*
Cypricardella nov. sp.
Posidonomya (probably nov. sp.)
Cardiomorpha sp.

Dr. Traquair also determined two of the fossils as *Acanthodes*, sp. and calcified cartilage of a Selachian.

Mr. Tait has also collected specimens from a fish bed above the Smithy Coal and about two fathoms below the Easter Main Coal at Bo'ness. The Smithy Coal is the lowest seam which is usually worked in the coal-bearing group of the Carboniferous Limestone Series in the Bo'ness district. The fishes from this bed have been referred to Dr. Traquair who has furnished the following report.

Dr. Traquair. "The fish remains collected by Mr. Tait from a shale the position of which is supposed to be between the Easter Main and Smithy Coals, Bo'ness, are as follows :—

Pleuroplax sp. (teeth).
Oracanthus armigerus, *Traq.* (teeth).
Tristychius minor, *Portlock* (spine).
Megalichthys sp. (scales).
Rhizodopsis sp. (scales).
Strepsodus striatulus, *Traq.* (tooth).
Cœlacanthus abdenensis, *Traq.* (jugular plate).
Eurynotus crenatus, *Agassiz*

This bed, which also contains abundant remains of *Lingula squamiformis* and *Discina nitida*, as well as a few species of marine Lamellibranchiata, which have been also collected by Mr Tait, belongs palæontologically to the same set of Lower Carboniferous "bone-beds' as those at Abden, Hyvots Mill, and Niddrie (shale in connection with the ' North ' Coal.) In these we have associated with *Lingula squamiformis* and sometimes with other mud-dwelling brachiopods and Mollusca, a fragmentary fish fauna especially characterised by *Oracanthus armigerus*, *Cœlacanthus abdenensis*, and *Eurynotus crenatus*. The constant association of these forms at different horizons is of considerable geological interest."

Dr. Crampton. Mr. Tait was also engaged during the autumn in collecting fossils from the Roslin Sandstone Series, in Sheet 31, with the view of fixing the palæontological boundary between the Upper and Lower Carboniferous rocks which has been proved to occur in Midlothian, and referred to in the Summary of Progress for 1903. The evidence obtained by him in the Lothians, in conjunction with the mapping of the Millstone Grit, was of much value in helping Dr. Traquair and Mr. Kidston to establish this line in Sheet 32, and his work in the autumn has shown that there is ground for the belief that it exists in the western areas. From

notes which he has furnished it appears that in the quarry at Garngad Road, Glasgow, ⅛ mile east of Garngad Road Railway Station, a shale under a parroty coal, five inches thick, yielded the following plants which have been determined by Mr. Kidston and contain Lower Carboniferous forms:— Dr. Crampton.

Calamites sp.
Sphenophyllum tenerrimum, *Ett.*
Rhodea sp.
Aphlebia sp.

and more than one species of Sphenopterid fern not yet determined but of Lower Carboniferous type. The Plant Bed is approximately 125 feet above the base of the Millstone Grit. At Messrs Steens' Fireclay Works, about 13 miles to the N.E. of this locality and ¼ mile E. of Castlecary Railway Station, a bed was discovered from which the following plants were obtained, which have been determined by Mr. Kidston:—

Lepidodendron aculeatum, *Sternb.*
„ obovatum, *Sternb.*
Sigillaria elegans, *Sternb.*
Sigillariostrobus
Lepidophloios sp.

The determinations are not yet completed, but the named species are Upper Carboniferous forms. The *Sigillariæ* are well preserved and *Sigillaria elegans* abundant. *Lepidodendron obovatum* was, however, also found in a coal at Gain near Glenboig, which is estimated to lie approximately 70 feet above the base of the Roslin Sandstone Series.

The strong resemblance of the marine bands in the lower part of the Roslin Sandstone Series of the western area to those of the Lothians was also noted by Mr. Tait. The fossils collected from one of these horizons have proved of special interest as regards the lamellibranch-fauna, as may be seen from the following report by Dr. Wheelton Hind:—

"A fauna, fairly rich in lamellibranchs, has been discovered by Mr. D. Tait at certain localities in the counties of Stirling and Linlithgow (Sheet 31). The strata consist of barren measures, sandstones, fireclays, thin limestones, and ironstones (Roslin Sandstone Series, Millstone Grit), which overlie the Carboniferous Limestone Series and underlie the Coal Measures. It further appears that the bands yielding the lamellibranchs occur at or about the junction of the Upper and Lower Carboniferous floras. Dr. Hind.

A very cursory examination of the material showed that the fauna contains a number of species hitherto unrecorded from Europe, so far as my knowledge goes, but on the other hand, it exhibits a remarkably close affinity to the lamellibranch-fauna described by Meek from the Coal Measures of Nebraska, Illinois, and other American States. Judging from Meek's descriptions and figures, I am of opinion that a very large number of the Scottish specimens are identical with the American species. It will be remembered that Geinitz referred many of the American

Dr. Hind.

forms to European Permian species (Carbonformation und Dyas in Nebraska, 1866) a view that Meek contested very strongly.

The most important feature of this new discovery is the presence in the Scottish collection of the genus *Prothyris*, Meek, hitherto known only from North America. The genus was erected by Meek on shells from the Coal Measures termed by him *P. elegans*, which I cannot distinguish from the Scotch specimens; but subsequently Hall showed that it was represented by one species from the Waverley Sandstone, twenty-eight species from the Hamilton, and two species from the Chemung group. The genus *Prothyris* in North America therefore ranges from the Devonian to the Coal Measures.

The Coal Measure fauna from Nebraska contains *Fusulina* and *Meekella*—genera not as yet known in Western Europe. In Russian Carboniferous rocks, both these forms are common in the zone of *Spirifer mosquensis*, which is higher than the Visean or *Productus giganteus*. It is, therefore, of the utmost importance that a thorough search should be made for any indication of these fossils in Scotland.

In the Midland Counties of England the *Productus giganteus* zone (the Upper *Dibunophyllum* zone of Vaughan) is succeeded by the Pendleside Series with its special fauna. This fauna does not seem to have existed north of the latitude of Settle 54° 4′ N. Two specimens in the Scottish series submitted to me, one from Glencryan (Sheet 31) and the other from one mile N.N.E. of Glenboig Railway Station, are probably *Posidoniella lævis*, a species typical of the Pendleside Series.

The species in this collection are referable to the following genera:—

Pterinopecten	Ctenodonta
Aviculopecten	Schizodus
Limatulina	Protoschizodus
Palæolima	Edmondia
Myalina	Sanguinolites or Pleurophorus
Posidoniella	Sanguinolites
Parallelodon	Allorisma
Nucula	Prothyris
Nuculana	Solenomya "

III. IRELAND.

The proofs of the "Cork map" and its accompanying Men were corrected in the early part of the year. The Map Memoir have been now published.

The Limerick Memoir was prepared so far as the superfi deposits are concerned.

The Irish Branch of the Geological Survey was transferred April 1st, 1905, to the Department of Agriculture and Techn Instruction for Ireland.

IV. MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

A. ENGLAND AND WALES.

I.—Maps.

One-inch Maps (New Series.)

The following new map has been issued:—

Sheet 141 (Loughborough).

The following Drift Maps previously issued hand-coloured have been replaced by colour-printed maps:—

Sheet 249 (Newport) Solid and Drift.
Sheet 267 (Hungerford).
Sheet 282 (Devizes).
Sheet 283 (Andover).
Sheet 284 (Basingstoke).
Sheet 299 (Winchester).
Sheet 316 (Fareham).
Sheet 332 (Bognor).
Sheet 334 (Eastbourne).

Six-inch Maps.

The undermentioned six-inch maps have been published with geological information uncoloured. Coloured patterns of these sheets have in each case been prepared and despatched to the Ordnance Office, so that on demand coloured copies of the sheets can be supplied—:

ENGLAND.

Derbyshire	57 S.W. Winshill.
	57 S.E. Repton Common.
	58 S.W. Ticknall (Leicester 9 S.W.).
	60 N.W. Newhall.
	60 N.E. Swadlincote (Leicester 15 N.E.).
	60 S.W. Linton (Leicester 15 S.W.).
	60 S.E. Blackfordby (Leicester 15 S.E.).
	61 N.W. Smisby (Leicester 16 N.W.).
Leicestershire	16 N.E. Worthington.
	16 S.W. Ashby de la Zouch.
	16 S.E. Thringstone.
	22 S.E. Appleby Magna.
	23 N.W. Packington (Derby 64 N.W.).
	23 N.E. Coalville.
	23 S.W. Heather (Derby 64 S.W.)

Leicestershire	23 S.E. Ibstock.
	29 N.E. Barlestone.
	31 N.W. Leicester Town, part of.
	31 N.E. ditto
	31 S.W. ditto
	31 S.E. ditto
	37 N.W. ditto Aylestone.
	37 N.E. ditto Oadby.

WALES.

Brecknockshire	43 N.W. Twrch Valley
	43 N.E. Tawe, part of.
	43 S.W. Cwm-twrch
	43 S.E. Seven Sisters.
	44 N.W. Ystradgynlais Higher.
	44 N.E. Ystradfellte.
	44 S.W. Tir-bach.
	44 S.E. Valley of the Neath, part of.
Glamorganshire	2 N.W. Cwm-amman, part of.
	2 N.E. Bryn-amman.
	2 S.W. Banc Cwm-Helen.
	2 S.E. Cwmgors.
	3 N.W., S.W., S.E., 4 S.W., S.E., see Brecknock 43 and 44.
	8 N.W. Cwm Clydach.
	8 N.E. Ynys-meudwy.
	8 S.W. Cwm Clydach, part of.
	8 S.E. Pontardawe.
	9 N.W. Ystalyfera.
	9 N.E. Dulais Valley, part of.
	9 S.W. Mynydd March-Hywel.
	9 S.E. Resolven.
	15 N.W. Clydach.
	15 N.E. Glais.
	15 S.W. Morriston.
	15 S.E. Neath Abbey
	24 N.W. Swansea.
	24 N.E. Briton Ferry.
	24 S.W. Mouth of the Tawe.
	24 S.E. Baglan Burrows.
	25 N.W. Cwmavan.
	25 N.E. Pont-rhyd-y-fen.
	25 S.W. Aberavon.
	25 S.E. Wyllt Valley, part of.
	26 N.W. Nantyffyllon.
	26 N.E. Blaengarw.
	26 S.W. Maesteg.
	26 S.E. Pont-y-Cymmer.
	33 N.W. South Aberavan.
	33 N.E. Margam Park.
	33 S.W. Margam Burrows.

Glamorganshire 33 S.E. Pyle, part of.
34 N.W. Llynfi Valley, part of.
34 N.E. Ogmore Valley, part of
34 S.W. Pyle, part of.
34 S.E. Aberkenfig.

Six-inch Reference Maps.

One hundred and seven MS. copies, coloured, of six-inch quarter sheets have been made from the field copies and deposited in the Library for Public Reference. These are as follows:—

Carmarthenshire.—54 S.E.; 57 N.E.; 58 N.W.

Cheshire.—56 S.W.; 62 N.W., N.E.

Cornwall.—34 N.E., S.E.; 35 N.W., S.W.; 42 S.W.; 57 N.E., S.W., S.E.; 58 N.W., S.W.; 64 N.W., N.E., S.W., S.E.; 70 N.W., N.E., S.W., S.E.; 71 N.W., S.W.; 82 (N.W. and S.W.); 82 (N.E. and S.E.); 83 S.W.; 86 N.E., (S.W. and S.E.); 87 N.W., N.E., S.W., S.E.; 87A N.W.; 88 (N.E. and S.E.); 89 N.W.

Derbyshire.—39 N.W., S.W.; 40 NE., S.E.; 41 N.W., S.W.; 44 N.W., S.W.; 45 N.E., S.E.; 46 N.W., S.W.; 49 N.W., N.E., S.W.; 50 N.E., S.E.; 51 N.W., S.W.

Essex.—66 N.W., S.W., S.E.

Glamorganshire.—21 N.E., S.W., S.E.; 22 N.W., S.W.; 30 N.W., N.E., S.E.; 31 N.W., S.W.

London.—1 S.E.; 2 N.E.; 3 S.W.; 4 N.W., S.W., S.E.; 5 N.E., S.E.; 6 N.W., S.E., S.W.; 7 N.W., S.W.; 8 N.E.

Middlesex.—15 N.W., S.W.; 19 N.W., N.E., S.E.: 20 S.W.; 7 N.E., S.W.

Northumberland.—4 N.W.; 5 N.E.; 10 N.W., N.E., S.W., S.E.

Nottingham.—32 N.E., S.E.; 37 N.E., S.E.; 38 S.E.; 41 N.E.; 41 S.E.

Staffordshire.—3 N.E.; 10 N.E.

Yorks 1 (whole sheet).

II.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom for 1904, pp. 184. Price 1s.

A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection, in the Museum of Practical Geology, pp. 241. By F. W. RUDLER, I.S.O., F.G.S. Price 1s.

The Geology of the North Staffordshire Coal-fields. By WALCOT GIBSON, B.Sc., F.G.S., with contributions by G. BARROW, F.G.S., and C. B. WEDD, B.A., F.G.S., and a Palæontological Account, with list of fossils by JOHN WARD, F.G.S., pp. 494. Price 6s.

The Geology of the Country South and East of Devizes (Explanation of Sheet 282). By A. J. JUKES-BROWNE, B.A., F.G.S., pp. 61. Price 1s.

The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la Zouch, and Loughborough (Explanation of Sheet 141). By C. FOX-STRANGWAYS, F.G.S., with a chapter on Charnwood Forest, by PROF. W. W. WATTS, M.A., M.Sc., F.R.S., pp. 83. Price 2s.

B. SCOTLAND.

I.—MAPS.

One-inch. Sheet 37, embracing the districts around Loch Awe (S. half); Loch Fyne (Upper half); and Loch Goil, Argyllshire.

Sheet 55, embracing the districts around Blair Atholl, Pitlochry, and Aberfeldy, Perthshire.

Six-inch. Skye 38, 39, 44, 45. Illustrating the Geology of the Cuillin Mountains and the Red Hills.

Six-inch Reference Maps.

Argyllshire.—138, 159.
Elgin.—21, 29.
Inverness.—2A, 2B, 11, 13, 18, 19, 22, 117, 132.
Nairn.—10, 12.
Ross.—26, 37, 38, 39, 51, 63, 108.
Edinburghshire.—12 N.E., SE.
Haddingtonshire.—9 S.W.
Peebles-shire.—1 S.E.
„ 2 N.W., S.W.

II.—MEMOIRS.

SHEET MEMOIRS.

The Geology of Mid-Argyll (Sheet 37). By J. B. HILL, R.N., B. N. PEACH, L.L.D., F.R.S., C. T. CLOUGH, M.A., and H. KYNASTON, B.A. with Petrological Notes by J. J. H. TEALL, D.Sc., F.R.S., and J. S. FLETT, M.B., C.M., D.Sc., pp. 166. Price 3*s*.

The Geology of the Country round Blair Atholl, Pitlochry, and Aberfeldy (Sheet 55). By G. BARROW, J. S. GRANT WILSON, and E. H. CUNNINGHAM CRAIG, B.A., with Petrological Chapter and Notes by J. S. FLETT, M.A., D.Sc., M.B. C.M., pp. 161. Price 3*s*.

LIST OF EXTRA OFFICIAL PUBLICATIONS.

ANDERSON, E. M.—The Dynamics of Faulting. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 387–402.

BAILEY, E. B., and D. TAIT.—On the occurrence of true Coal Measures at Port Seton, East Lothian. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 351–362.

———— On the occurrence of two Spherulitic ("Variolitic") Basalt Dykes in Ardmuchnish, Argyll. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 363–371.

CRAIG, E. H. CUNNINGHAM.—On the Igneous Breccia of the Lui near Braemar. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 336–340.

CRAMPTON, C. B.—The Limestones of Aberlady, Dunbar and St. Monans. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 374–378. A possible mode of Inheritance of Adaptive Characters. *Proc. Roy. Phys. Soc.*, vol. xvi., pp. 62–75.

GOODCHILD, J. G.—On Unconformities and Palæontological breaks in relation to Geological time. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 275–314.

HARKER, A.—The Tertiary Crust Movements in the Inner Hebrides. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 344–350.

HILL, J. B.—Geology of Cornwall. *Victoria History of the Counties of England.*

HOWE, J. A., and J. S. FLETT.—Attrition Tests of Road-making Stones. *The Surveyor*, vol. xxviii.

———— and G. F. J. PREUMONT.—Notes on the Geological Aspect of the North-East Territories of the Congo Free State. *Quart. Journ. Geol. Soc.* vol. lxi.

LAMPLUGH, G. W.—Abstract of Report on the Batoka Gorge of the Zambesi. *Nature*, Nov. 30th, 1905, vol. 73.

———— Notes on the Geological History of the Victoria Falls. *Geol. Mag. dec. v.*, vol. ii., pp. 529–532, Dec. 1905.

NEWTON, E. T. (with H. H. ARNOLD-BEMROSE).—On an Ossiferous Cavern of Pleistocene Age at Hoe-Grange Quarry, Longliffe, near Brassington (Derbyshire). *Quart. Journ. Geol. Soc.*, vol. lxi., pp. 43–62.

PEACH, B. N.—The Higher Crustacea of the Carboniferous Rocks of Scotland. *Trans. Geol. Soc. Edinr.*, vol. viii., pp. 372–373.

———— and J. HORNE.—Notes on the Geology of the Shin Basin. *Geogr. Journ.*, vol. xxvi., pp. 533–534. Nov. 1905.

———— Notes on the Geology of the Conon Basin, *Geogr. Journ.*, vol. xxvi., pp. 63–68. July, 1905.

REID, C.—The Island of Ictis. *Archæologia*, vol. lix. 1905.

THOMAS, IVOR.—Nene Beiträge zur Kenntnis der devonischen Fauna Argentiniens. *Zeitschrift der deutschen geologischen Gesellschaft, Berlin.* 1905.

WOODWARD, H. B.—Report on the Wells and Sewage Farms on the War Department Land on Salisbury Plain. 1904. Fol. London.

———— Excursion to Bedford. *Proc. Geol. Assoc.*, vol. xix., pp. 142–146.

———— Geology of Buckinghamshire. *Victoria History of the Counties of England.*

APPENDIX.

I. On the Petrographical Characters of the Inliers of Lewisian Rocks among the Moine Gneisses of the North of Scotland.

By John S. Flett, M.A., D.Sc.

During recent years the members of the Geological Survey who have been engaged in mapping the Northern Highlands under the superintendence of Dr. Peach, Mr. Clough, and Mr. Hinxman have reported the occurrence of inliers consisting of a variety of crystalline rocks of Lewisian facies among the Moine gneisses east of the Moine thrust plane. A considerable amount of petrographical material from these inliers has been sliced and microscopically examined and seems of sufficient interest to deserve a brief general description. A great number of different types, essentially of Lewisian facies, are represented in this collection. Most of them have no parallel among the Moine rocks. A few, however, of the more acid gneisses with muscovite and biotite might belong, so far as their composition and structure are concerned, to either group. Practically all of the supposed Lewisian rocks can be very closely paralleled in the admittedly Lewisian areas farther to the west, but certain of their structures indicate an approach to the characteristic granulitic texture of the Moines. Of the gneisses of the Lewisian outcrops the majority are igneous (plutonic, intrusive) gneisses or orthogneisses, but there are also metamorphosed sediments (paragneisses) such as calc-silicate rocks and graphitic schists. The occurrence of andalusite and other "contact minerals" in some of the latter would indicate that they are older than, and have been contact-altered by some of the intrusive members of the Lewisian.

In sheet 119 of the Geological Survey one-inch map of Scotland (Tongue) areas of Archæan (Lewisian) are shown outcropping among the Moine rocks east of the Kyle of Tongue. This map was published in 1889, but no description of it has appeared, and it seems that the relations of these Lewisian areas to the surrounding Moines was regarded at the time as an open question.

In 1895 Dr. B. N. Peach called attention to the existence of areas among the Moine gneisses in the basin of the River Bran, consisting of rocks which strikingly resembled the Lewisian gneisses of Western Ross-shire.* The district to which he referred lies a few miles south of Achnasheen, and forms the large inlier of Lewisian rocks indicated a little north of the centre of the accompanying sketch map. Dr. Peach was of opinion that his observations proved that the schistose rocks forming the country to the east of the great

*Annual Report of the Geological Survey for 1895, pp. 19 and 20 (1896).

thrust-planes, consist partly of detached masses of Lewisian Gneiss and partly of an overlying series of sedimentary deposits (Moine gneisses and granulites). In some places the actual unconformable junction of the pebbly or conglomeratic base of those sediments with the gneiss can be made out, but in an inverted position. At the head of the River Bran, where the large area of gneiss above referred to is succeeded by Moine schists, the line of junction between the two groups of rock is suggestive of an unconformability, the individual highly contorted bands of the gneiss appearing to be abruptly truncated by the schists.

Further particulars of some of these inliers were given by Dr. Peach in 1898. In that year he had mapped an additional part of the area above referred to and found that it contained biotite gneisses, hornblendic gneisses, hornblende schist and epidiorite. "Ultrabasic rocks are also present which appear to have been peridotites though now for the most part in the condition of unctuous schists with clear colourless amphibole. Epidote is a common mineral in most of the masses. The general assemblage of these rocks, together with their mode of occurrence, at once recalls the Lewisian gneiss as developed at Loch Alsh, Glenelg, Shieldaig, and many other parts of the West Coast."*

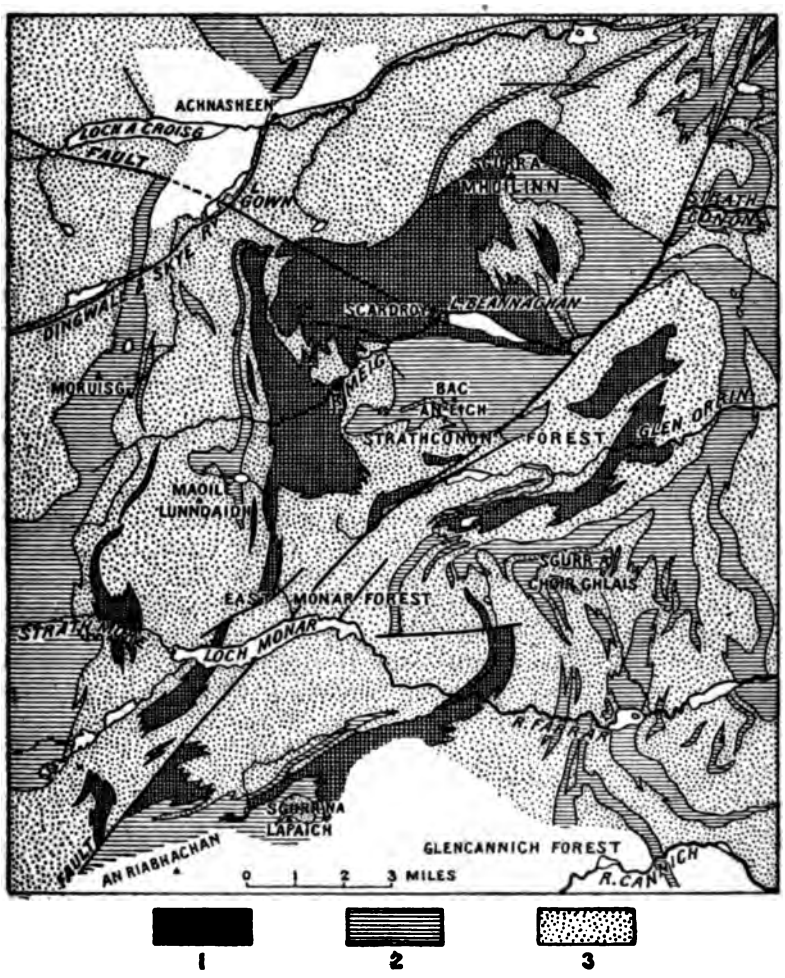
During the field season of 1898 Dr. Peach encountered another mass of Lewisian rocks some distance to the east of that above referred to. It lies about three miles north of Loch Luichart station, and only its north-western extremity is indicated in the north-east corner of the accompanying sketch map. One fact about this inlier is worthy of special mention; it was the first to provide specimens of the sedimentary rocks and paragneisses of the Lewisian. Dr. Peach reported that in addition to the types of rock already mentioned, this mass includes a white and a pink crystalline marble with calc silicates much like the limestone of Glenelg. "In both tracts the junction between the Moine schists and the older gneisses wherever seen is quite sharp, and while the character of the overlying rock remains constant, that of the lower series varies from one exposure to another—a relation which suggests the inference that the junction between the two groups is an unconformable one.†"

In the Glenelg district, east of the Moine Thrust, Mr. Clough grouped the crystalline schists in two series: (1) those which he ultimately referred to the Lewisian gneisses, (2) the Moine schists. The most noteworthy types of rock included in the former series, some of which he regarded of sedimentary and others of igneous origin, are: 1, marble; 2, graphitic gneiss; 3, garnetiferous biotite gneiss or schist with kyanite; 4, finely laminated rocks with some resemblance to mylonites; 5, eclogite; 6, pyroxenite; 7, hornblende schist; and 8, banded gneisses. He pointed out that many of the hornblende schists in the Lewisian gneiss series are intimately connected with the eclogites and that one of these bands on the east side of Eilean Donnan, which cuts the first foliation of an acid

* Summary of Progress of the Geological Survey for 1898, p. 7 (1899).
† Summary of Progress of the Geological Survey for 1898, p. 9 (1899).

biotite gneiss, may be of the same age as the Scourie Dykes of Sutherland. In the Annual Summary for 1899, page 17, he described the relations of the Moine schists to the Lewisian gneiss of that district, from which he inferred that the boundary is

FIG. 3. *Map to show position of inliers of Lewisian gneiss among the Moine schists, Strathconon Forest.*



1. Lewisian gneisses and schists.
2. Micaceous schists and gneisses (pelitic gneisses) of the Moine series.
3. Granulitic gneisses (psammitic gneisses) of the Moine series.

either a line of thrust or that the former are younger than the Lewisian gneiss and unconformable to it. The absence of any important thrust and the occurrence of a band with fragments of pink felspathic gneiss resembling a highly conglomeratic or

boulder bed at the junction of the two groups near Rudha na h' Airde Beithe, led him to regard the latter interpretation as the more probably one.*

During subsequent years Mr. Hinxman, Mr. Anderson, Mr. Carruthers and Dr. Crampton, mapping the district to the south of that described by Dr. Peach, have repeatedly met with inliers of Lewisian gneiss among the Moine rocks. Mr. Hinxman in 1902 recognised two such infolds, one in Glen Orrin (represented in the accompanying map), and another further to the east and just outside the map. Both contained biotite and hornblende gneisses with representatives also of the more basic types of the Lewisian.† In 1904 he continued the mapping of the large inlier noted by Dr. Peach, surveying principally that part which lies next Scardroy and Loch Beannachan. Mr. Carruthers, Dr. Peach, and Dr. Crampton traced the extensions of this inlier to the west and south-west across Loch Morar, while Mr. Anderson mapped part of the Glen Orrin inliers. The result of their work was to shew that in these inliers occurred a great variety of types of gneiss, acid, basic and ultrabasic, closely resembling those of the Lewisian country west of the Moine thrust-plane and to strengthen the probability that these rocks were covered unconformably by the Moine series.

In the field seasons of 1902 and 1903, Mr. Cunningham Craig mapped an area consisting of limestone, kyanite schist, and ultrabasic rocks in Glen Urquhart, which he regarded as probably of Lewisian age.§ This forms the most south-easterly extension of these inliers at present known. In the Summary of Progress for this year (1905), many additional details will be found regarding the distribution of these Lewisian rocks in Glen Meig, Glen Orrin, and the adjoining districts. The result of the mapping up to the present time is strongly to confirm the conclusions originally arrived at by Dr. Peach as to the Lewisian age of the inliers, and the probability that between them and the overlying Moine gneisses there is an unconformability.‖

IGNEOUS GNEISSES (ORTHOGNEISSES) OF THE LEWISIAN INLIERS.

By far the commonest kind of rock in these Lewisian inliers is *hornblende gneiss*, consisting essentially of green hornblende, orthoclase and plagioclase felspar, and quartz. The foliation is sometimes very perfect, passing occasionally into a straight

* Summary of Progress of the Geological Survey for 1897, p. 37; for 1899, p. 14, *et seq.*; for 1900, p. 8; for 1901, p. 96; also see paper "On Spinel and Forsterite from the Glenelg Limestone," by C. T. Clough and W. Pollard, *Quart. Journ. Geol. Soc.*, vol. lv. pp. 375–376.

† Summary of Progress of the Geological Survey for 1902, p. 88 (1903).

‡ Summary of Progress of the Geological Survey for 1904, pp. 74 *et seq.* (1905).

§ Summary of Progress of the Geological Survey for 1902, p. 89 (1903) and for 1903, p. 84 (1904).

‖ See pp. 103–109.

parallel banding, but at other times may be almost wanting, and the resemblance to granites, tonalites, and diorites in the hand specimens is then very great. The abundance of the essential ingredients varies greatly, some specimens being pink and highly quartzo-felspathic, while others are dark and rich in hornblende. The amphibole is similar to the common green hornblende of granites and diorites, but is occasionally brownish-green in thin section. Oligoclase and albite (or oligoclase albite) are on the whole more common than orthoclase, but both are probably always present; microcline and varieties of plagioclase more basic than oligoclase, are very rare. The accessory minerals, sphene, apatite, magnetite, and zircon are usual in the slides. Epidote is commonly so abundant that it might almost be regarded as a characteristic and essential mineral, and very frequently it contains brown cores of idiomorphic or hypidiomorphic orthite. The darker or femic hornblende gneisses contain least orthoclase and quartz. They pass gradually into rocks which may be described as *amphibolites* or *epidote amphibolites*. Many of these contain large pink garnets, dotted with enclosures of quartz and magnetite. Garnet appears also in the hornblende gneisses, but is far less common there.

The prevalent epidote is pale yellow in thin section and bright yellow in the hand specimen. Its abundance was noted by Dr. Peach as characteristic of the Lewisian gneisses.* It is rare in the Moine granulites as a rule, though a colourless or pale grey clinozoisite or zoisite characterises certain bands of the Moines which have been described as zoisite granulites and zoisite hornblende granulites†. There is little danger, however, of confounding these rocks, which are evidently metamorphosed calcareous sediments, with the epidote hornblende gneisses of the Lewisian. Still more distinctive is the great frequency with which orthite occurs in the latter rocks. This mineral has only once or twice been seen in the Moine granulites, but is exceptionally abundant in some of the more acid gneisses of the Lewisian inliers. It is always surrounded by a narrower or broader border of epidote in parallel growth. The whole aggregate is usually not idiomorphic, though the orthite centre frequently shows good crystalline outlines.

Pyroxene hornblende gneisses. — The hornblende gneisses occasionally contain crystals of pyroxene, bright green in colour, and in the microscopic slides paler than the accompanying hornblende and far less dichroic. Usually its amount is small, but sometimes it nearly completely replaces the amphibole, without, however, producing any very marked change in the macroscopic appearance or in the structure of the rock. Its prismatic cleavage is usually very good, and occasionally a fine striation

* Summary of Progress of the Geological Survey for 1898, p. 7.

† Annual Reports of the Geological Survey for 1897, p. 41; 1898, p. 13; 1899, p. 40. Memoirs of the Geological Survey (Scotland), Lower Strathspey, p. 47 (1902).

appears parallel to the basal plane. The extinction angle is about 40°. Both the amphibole and the pyroxene are in short, irregular grains, which show little trace of crystalline form. Either mineral may enclose patches of the other, usually not in parallel growth. Orthoclase and acid plagioclase, quartz, magnetite, epidote, are the other components. Sphene is often abundant, and may have a strong brown colour and distinct dichroism. Biotite and orthite are rare. In one of these rocks from Allt Toll a Mhuic (11,632), the epidote is pale yellow green, like the pyroxene, very feebly dichroic, and is penetrated in all directions by intergrowths of quartz, so that it resembles vermicular micropegmatite. Other specimens came from Meall Cosach, and Allt Riabhaichain.

Nodules or streaks of bright yellow colour, composed of epidote and augite with a little quartz, hornblende, iron ores, and sphene sometimes occur in the hornblende gneiss. They are essentially of the same nature as the epidosite segregations frequently observed in hornblendic schists, but the abundance of augite in them is a distinctive feature. They do not seem to form any considerable mass of rock. Their epidote not unfrequently has fairly good crystalline faces, but the augite and quartz are always irregular. Other *epidosites* which may also contain bright green pyroxene, occur in connection with the marbles and calc-silicate rocks and may be altered sediments.

Though many of the hornblende gneisses are free from biotite, this mineral is a very common ingredient of them, especially of those which are comparatively rich in felspar and in quartz. It is always brown, strongly dichroic (pale yellow brown to dark brown, nearly black) and is often aggregated into clusters or separate folia with the amphibole. The *biotite hornblende gneisses* are more frequent than the *pyroxene hornblende gneisses* and mark transitions to the *biotite gneisses*—free from hornblende—and the *muscovite biotite gneisses*. They are readily detected in the hand specimen by the lustrous mica coating the cleavage planes. Gneisses containing muscovite are scarce. They are relatively quartzose, and often rich in microcline and orthoclase; sphene is rare in them, but the epidote and orthite above described are almost constantly present, and are often conspicuous in the micro-slides. A little vermicular micropegmatite also is frequent, but garnet has not yet been found in any of the acid orthogneisses. The *pegmatite veins* so characteristic of the Lewisian area west of the Moine thrust-plane occur also in these inliers, being represented by pale gneisses consisting mainly of quartz and orthoclase with a small amount of both black and white micas.

Allied to the garnetiferous amphibolites above-mentioned as forming the femic end-facies of the hornblende gneisses are certain rocks consisting of large garnets, green hornblende, pale green augite and quartz. These may be classed as *eclogites*. They are not numerous, but both their presence and their association with altered sedimentary gneisses is of considerable significance as linking certain Lewisian inliers with the old

gneiss of the Loch Maree area. In these eclogites there are very many garnets, both large and small, pink in section and giving the rock a brownish colour in the hand specimen. Quartz is abundant in certain folia; felspar is absent; the hornblende is pale green and only feebly dichroic; the augite clear green and weathering to grass green amphibole. Much of the augite has basal striation; magnetite, rutile and apatite are present, but the ubiquitous epidote is almost absent. With the exception of the rutile none of the ingredients shows any crystalline form. The amphibole often surrounds the augite in parallel growth and the larger crystals of both minerals are spotted with rounded enclosures of quartz. The best example of the eclogites is one sent in from An Cruachan by Dr Crampton. (12,421).

The structure of these gneisses, amphibolites and eclogites is generally that which has been designated homœoblastic by Becke and granoblastic by Grubenmann.*

The main ingredients are all of very similar size and devoid of crytalline outlines. Rutile, sphene and occasionally apatite and iron ores form well shaped, though small crystals, but they are the only exceptions to the general rule. Hornblende is granular rather than elongated; augite occurs only in rounded grains; the garnet, quartz and felspar never show any but the most rudimentary crystalline outlines. When much mica is present there is a tendency to the development of minute foliation, but this occurs so seldom that it is never of importance. Occasionally the larger crystals of certain minerals such as garnet and felspar are studded with small rounded enclosures of quartz (poikiloblastic structure). The orthite is usually partly idiomorphic, but the epidote which surrounds it has less commonly crystalline boundaries. Although these rocks are all of igneous origin their igneous structures have been completely defaced by the action of metamorphic agencies.

The *ultrabasic rocks* (peridotites, etc.) which occur in the Lewisian gneiss west of the Moine thrust-plane, whether as members of the fundamental gneiss or as dykes of later age intersecting it, occur also in these inliers. They are represented mostly by unctuous dark green schists composed of pale coloured talc, chlorite and tremolite or actinolite. Iron ores and apatite are the usual accessories, and a small percentage of carbonates (mostly calcite) is very commonly also present. The principal minerals are chlorite and talc; their relative proportions vary considerably, but talc usually preponderates. The chlorite is of that variety which gives grey polarisation colours and is usually polysynthetic (clinochlore). The tremolite is colourless or very pale green in thin section, contains few enclosures and has imperfectly idiomorphic transverse sections. These rocks are schistose in structure.

In several of the specimens undestroyed crystals of olivine and

* F. Becke, Ueber Mineralbestand und Struktur der kristallinischer Schiefer. Compte Rendu de la IX. Session du Congrés Géologique Internationale (Vienna, 1903) p. 571. 1904.
Grubenmannr Die kristallinen Schiefer I., p. 79. 1904.

other minerals remain, weathering to serpentine and surrounded by a winding (helizitic or nematoblastic) schistose matrix of talc, tremolite and chlorite. These rocks consequently exhibit the relict structure (Becke) or palimpsest structure (Sederholm)* which arises from the incomplete transformation they have undergone.

Near Carnock, Strathconon, Mr. Hinxman has mapped talc-chlorite-tremolite schists, tremolite schists, and talc-tremolite schists with kernels of olivine, in one of the Lewisian inliers. These rocks contain a variable quantity of calcite and iron oxides. The olivine is weathering by ordinary epigenetic processes to a meshwork of green serpentine, which lines the cracks and covers the surface of the original mineral. An interesting ultrabasic rock from Sleugach, R. Orrin, consists principally of colourless polysynthetic clinochlore, with acicular tremolite. In this matrix lie masses of olivine weathering to a network of serpentine and magnetite, the interstices of which contain still fresh olivine, and large crystals of nearly colourless pyroxene, the cracks of which are edged with bright yellow chloritic decomposition products. At Carn-na-Creadha there is a tremolite rock with large green pseudomorphs after pyroxene crystals; these are composed of a mixture of talc, chlorite and serpentine. Highly schistose talc-chlorite schists occur on the Allt Riabhaichain. Serpentines with tremolite, chlorite and olivine have also been mapped in Glen Urquhart by Mr. Cunningham Craig.

A very peculiar dark schistose rock, rich in lustrous biotite, which Dr. Crampton obtained in one of the ultrabasic parts of the Lewisian on the Allt Riabhaichain may perhaps represent some of the *pyroxenites* which are familiar in that formation. It is a pyroxene biotite hornblende schist which contains much pale green, feebly dichroic amphibole, and small grains of bright green pyroxene with imperfect cleavages. A little talc, magnetite and chlorite, and small patches of calcite are also present. The rock is schistose in the hand specimen, and has been very completely metamorphosed from its original state. None of its ingredients is idiomorphic.

That the whole of the rocks above described are igneous is evident from their bulk composition, and the paragenesis of their minerals. They form a complete and continuous series parallel to the granites, tonalites, diorites, gabbros, and peridotites of plutonic origin. This conclusion is not affected by the fact that some of them may represent the granitic, doleritic, or ultrabasic veins and dykes which intersect the Lewisian gneiss. The great diversity of rocks which may occur in a single small outcrop is also significant. A small hand specimen may yield three or more micro-slides which might be relegated to different groups, These are essential features of the Lewisian gneiss as they have been described by all geologists who have investigated it.†

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* Grubenmann, Die kristallinen Schiefer I, p. 83, 1904.

† For an account of the petrography of the western Lewisian gneisses see Dr. Teall in Annual Report of the Geological Survey for 1895, p. 280.

The Lewisian, though in one sense a definite entity, is when closely examined a great complex embracing many different types and structures, and having, no doubt, a long and intricate history. But this complexity repeats itself in these inliers and is equally conspicuous in them. Of the Lewisian rocks which lie to the west of the Moine thrust only one important group is absent, the pyroxene granulites rich in hypersthene. No hypersthene has as yet been detected in the gneisses of the inliers. Epidote is more common in the latter rocks than in the main Lewisian masses, but even in these it is by no means infrequent. Orthite is certainly unusually common in the rocks in question, but it is also present in certain Lewisian gneisses from the Loch Maree area. Veins consisting mainly of orthite have lately been reported from the Lewisian rocks of the Glenelg district. Moreover, the amount of epidote is known to increase as the unconformable junction between the Archæan and the Torridonian is approached, and it is believed by the geologists who have mapped the ground that Dr. Peach was right in suggesting that the Lewisian inliers occupy their present position, not on account of thrusts or dislocations, but are upholds of a platform on which the Moines were unconformably laid down.

SCHISTS AND GNEISSES OF SEDIMENTARY ORIGIN (PARAGNEISSES) WITH MARBLES AND CALC-SILICATE ROCKS.

Rocks of the above groups occur in most of the Lewisian inliers. Pure marbles have not as yet been met with, but granular, crystalline, rather coarse-grained rocks consisting principally of calcite with considerable amounts of pale green augite (malacolite), pale green or colourless hornblende (tremolite), and nearly white uninaxial biotite (or phlogopite) are frequent (*Cipolins*). The commonest accessories are sphene, epidote (and zoisite) iron oxides, quartz, untwinned or simply twinned alkali felspar (including albite), apatite and zircon. By a diminution in the amount of calcite, these pass into tremolite and malacolite rocks. They have mostly a massive rather than a schistose structure.

Certain pale yellow epidosites, which occur along with the calc-silicate bands in the inliers may belong also to this group of altered sediments. They consist, as above-mentioned, of epidote, augite and quartz, with felspar and sphene. The epidote is pale yellow, the pyroxene pale green, and they are often not easy to distinguish from one another. Calcite appears in small quantity in some of these rocks. The felspar is mostly untwinned alkali felspar.

Another interesting group of calc silicate rocks contains scapolite. The best example yet obtained in the Scardroy district comes from Allt Coire Dubh in the ground mapped by Mr Hinxman. It is a grey, fine-grained, banded rock, like a fine gneiss. Its principal ingredients are scapolite, augite, and hornblende. The pyroxene is granular and nearly colourless

but quite anidiomorphic. Pale green hornblende is nearly equally common with the augite. Its crystals also are irregular and its pleochroism not strong. Scapolite is very frequent both in a fresh and in a weathered condition. It forms small grains rarely showing traces of crystalline form, and with the characteristic tetragonal cleavage well marked. When it decomposes it becomes turbid and between crossed nicols the bright colours and simple structure of the original mineral are replaced by a mosaic of pale grey. It has been converted into a mineral with lower double refraction, lower refractive index and biaxial character. Careful examination shows that the new mineral is alkali felspar. Primary felspar, mostly oligoclase, occurs also in the rock, but is always perfectly fresh and clear, while the secondary felspar is turbid and cloudy. Moreover, the primary felspar forms simple grains of rounded shape, the new felspar forms pseudomorphs after scapolite, having the external shape of the original mineral but composed of a number of small grains with indefinite orientation and very irregular boundaries. This method of decomposition in scapolite has long been known in large crystals, as for example in the albite pseudomorphs after scapolite from Krageroe, in Norway, but does not seem to have been hitherto recorded in the smaller scapolite crystals of rocks. Biotite and sphene are also present in the sections and apatite seems to be exceptionally abundant.

It may be noted also that in the limestone of Gortally, Glen Urquhart, scapolite has long been known to occur.*

There are also dark *muscovite biotite schists* well foliated and containing small garnets, quartz, oligoclase, albite and iron oxides. These rocks are not distinguishable from certain phases of the muscovite biotite schists of the Moines. Another group of paragneisses includes highly quartzose *muscovite schists*, free from biotite, and approaching quartz schists. In addition to quartz and muscovite they contain many grains of yellow epidote, a little zircon and iron ores, but little or no felspar.

Kyanite occurs in a muscovite biotite schist or fine grained gneiss, which Mr. Cunningham Craig obtained at Gortally on Glen Urquhart. It is abundant at this locality and forms blue, bladed crystals nearly half an inch in length. Still more important is the presence of a *graphite schist* with crystals of *andalusite* on An Cruachan. It is a dark grey, highly schistose rock which stains the fingers and readily marks paper. The microscopic section shows scaly graphite, pale brown biotite, quartz, oligoclase, iron ores and granular sphene. A little muscovite appears also in the more quartzose folia. The garnet takes the form of small crystals arranged in streaks or folia parallel to the banding of the rock. It has often a weak double refraction and seems to be decomposing into quartz and chlorite. And alusite occurs in numerous large colourless crystals, almost

* M. F. Heddle—The Mineralogy of Scotland, vol. ii., p. 33, 1901

free from enclosures. Their outlines are irregular. This rock is evidently a contact product.

The igneous gneisses of the Lewisian inliers are sharply distinguished from the Moine rocks by the fact that these latter are, in the vast majority of cases, clearly altered sediments. Many of them are highly quartzose (psammitic gneisses), others are full of biotite (pelitic gneisses and schists). Only a few of the acid muscovite biotite gneisses of the Lewisian inliers at all resemble in composition the common rocks of the Moines. In structure there is also a marked difference, though this is not easy to describe in words. In particular, the very perfect round-grained texture, so typical of vast numbers of Moine gneisses,* does not show itself in the Lewisian rocks. Even the hornblende schists of the latter group are distinguishable as a rule by certain minor characteristics from the epidiorite sills intrusive into the Moine. Above all, the Moine formation is restricted to a comparatively small number of rock types; the Lewisian is richly diversified, and most of its members have no correlates in the Moine Series.

Similarities in structure and composition might be expected to be greatest in the sedimentary rocks of the two formations; and this is undoubtedly the case, especially in the mica schists, which often cannot be distinguished from one another. But in the Moines calcareous sediments are rare; and no marbles or cipolins have been observed in them where they are typically developed. Such rocks, however, are a characteristic part of the Lewisian in certain areas (Glenelg, Loch Maree, etc.). If confirmatory evidence were required as to the Lewisian age of these inliers, none better could be adduced. Graphite also is foreign to the Moine rocks, but not rare in the Loch Maree series.

The kyanite gneisses and andalusite schists are of special interest. Similar kyanite-bearing rocks occur at Carnmore (Loch Maree), but andalusite is not known at that locality. This may perhaps be explained by the known tendency of andalusite to change to kyanite under certain conditions of metamorphism. It has long been supposed that the paragneisses of the Loch Maree series may possibly represent some of the sedimentary rocks into which the Lewisian orthogneisses were intruded.† This seems to be the most feasible explanation of the occurrence of andalusite schists in association with the orthogneisses of Lewisian type in the An Cruachan inlier. In any case the analogy with the Loch Maree succession is complete.

The presence of this sedimentary formation distinct from the Moines and underlying them also debars us from supposing that the Lewisian orthogneisses are intrusive into the Moine rocks themselves. Masses of 'older granite,' highly sheared and gneissose, are known (Garve, Carn Chuinneag, etc.) to penetrate the Moines and to produce various kinds of hornfelsed rocks,

* G. Barrow, "The Moine Gneisses of the East Central Highlands." *Quart. Journ. Geol. Soc.*, vol. lx., pls. xxxiii, etc., 1904.

† Sir A. Geikie, *Textbook of Geology*, 4th ed., vol. ii., p. 890. 1903.

andalusite and kyanite schists, from their more argillaceous members. But these intrusions bear little resemblance to the Lewisian orthogneisses either in the field or under the microscope, and the rocks they are injected into are quite distinct from the marbles, calc-silicate rocks and graphitic schists of the inliers. These facts remove any doubt that may cling to the interpretation of the junction between the two formations, for there are evidently *two* sedimentary series, differing widely in essential characters. The lower of these rests upon and has been contact altered by some part of the great Lewisian orthogneiss, but the Moine gneisses show no such changes as they approach their boundary lines. The Lewisian sediments are sometimes present, but more frequently are absent in the inliers.* If they were the original overlying mass into which the Lewisian orthogneisses or the latest members of that group were injected they must have been partly removed by denudation before the Moines were deposited.

DESCRIPTION OF PHOTOMICROGRAPHS.

PLATE IV.

Fig. 1. Slide No. 10,607. Magnified 10 dia.
Meall Cosach, Glen Orrin, Ross.

Pyroxene Hornblende Gneiss. — The photograph shows many sections of hornblende (dark) mixed with granular pale-green augite. The cleavage of the hornblende is visible to the right. A band of quartz and felspar crosses the field below. Epidote is also present, but cannot be distinguished from the augite. Small grains of dark-brown sphene are enclosed in the amphibole, surrounded by pleochroic halos.

Fig. 2. Slide No. 12,421. Magnified 19 dia.
An Cruachan, Ross.

Eclogite.—This rock consists of quartz, garnet, augite and hornblende, with apatite, iron ores and pyrites. The garnets are pink, rounded, and contain enclosures of quartz, magnetite, hornblende, etc. The augite and hornblende are both green and may be distinguished most readily by their cleavages; they are often in parallel growth.

Fig. 3. Slide No. 11,380. Magnified 19 dia.
N.N.W. of Carnock, Strath Conon, Ross.

Peridotite.—Ultrabasic part of Lewisian. A large crystal of olivine which is being serpentinised after the usual manner, lying in a matrix of polysynthetic pale-green chlorite and colourless tremolite. The latter shows its cleavage and its higher refractive index. Grains of apatite and iron-oxide are also visible in the section.

* Summary of Progress of the Geological Survey for 1903, p. 79 *et seq.*

Fig. 4. Slide No. 12,313.B. Magnified 19 dia. Allt Coire Dubh, Ross.

Scapolite Pyroxene Hornblende Gneiss. The photograph shows, in the upper part, clear areas of quartz and perfectly transparent felspar (oligoclase), mixed with crystals of green hornblende. The lower part of the field is composed mostly of scapolite, colourless but decomposing; near the bottom there is a cross section of this mineral with tetragonal cleavage. Mixed with the scapolite is much granular augite (nearly colourless in the slide); it can be distinguished by its rough surface and strongly marked borders.

Fig. 5. Slide No. 10,898. Magnified 10 dia. Lower Gortally, Inverness.

Kyanite Gneiss.—The slide shows large crystals of kyanite, colourless in section and easily distinguished by their perfect cleavage and high refractive index. Biotite and muscovite are both abundant, and the colourless matrix is quartz.

Fig. 6. Slide No. 12,422. Magnified 19 dia. An Cruachan, Ross.

Andalusite Graphite Schist.—A large rough irregular crystal of colourless andalusite lies in the centre of the field. The black patches are graphite and iron ores. The clear areas are mostly quartz. A pale yellow biotite is also present in irregular parallel scales. Another crystal of andalusite is visible at the bottom of the field.

II. Notes on Recent Excavations in the London Area.

By George Barrow, F.G.S.

During the past year considerable additions have been made to the knowledge of the London area, chiefly from four sources—

1. The Underground Electric or Tube Railways.
2. The Rotherhithe Tunnel works.
3. The Cuttings on the Great Central Railway near Gerrard's Cross.
4. The Engineering Department of the London County Council.

1. A detailed account has been obtained of most of the shafts and borings of the Tube railways, and in addition notes have been supplied and specimens sent of any interesting section met with in the tunnel.

The rocks penetrated in these works consist of Thames Valley Deposits, the Bagshot Sands, London Clay and the Woolwich and Reading Beds.

The last named were met with on the Waterloo and Baker Street line, a little north of the "Elephant and Castle," and the beds consisted of gravel and sands with shells. The evidence

collected elsewhere makes it clear that these sands are at least 30 feet below the top of the Woolwich Beds. As there is no record of the mottled clays, the latter are either included with the London Clay, or these shelly sands are faulted, as well as being brought up on the crest of an anticline. As the works were not complete when the latest information was obtained there is still a chance of ascertaining if the mottled clays or marls were met with or not.

On the north side of the Thames the Woolwich and Reading Beds have been penetrated in the tunnels in three areas (*a*) between Covent Garden and King's Cross; (*b*) between Oxford Street and Euston Station; (*c*) on the south side of Regent's Park. At Covent Garden the mottled clay rises naturally from below the London Clay, the junction, which was personally inspected, being clean and sharp as usual. Further north the junction between the two series is a fault in at least two instances, and in one case it is a reversed fault, as noted by Mr. Clement Reid a few years ago.

In the section between Euston and Hampstead Road a considerable amount of water was met with in some sand beds in the middle of the mottled Reading clay. To keep out the water the work was carried on under air pressure for a considerable time. After seeing the tunnel it was suggested that if a bore was put down to the chalk the water would drain away naturally. To test this a bore was made some feet into the Chalk, and by this means a complete section of the beds was proved, which is as follows:—

		Ft.	In.
Superficial Deposits		25	0
Blue Clay	London Clay	26	0
Brown Sandy Clay	London Clay	3	6
Brown Clay	London Clay	5	6
Mottled Clay	Woolwich and Reading Beds	22	0
*Loam and Sand	Woolwich and Reading Beds	15	0
Mottled Clay	Woolwich and Reading Beds	21	0
Green Sand, Small Stones and Clay	Woolwich and Reading Beds	11	0
Pebbles and Green Sand	Woolwich and Reading Beds	9	0
Sand	Woolwich and Reading Beds	5	6
Thanet Sand		12	6
Green-coated Flints		1	0
Chalk			

The water-bearing beds vary in thickness from as much as 15 feet to a foot or two, and apparently die away altogether at times. They have a constantly rising and falling surface, but whether this is due to movements or to underlying "pipes" or pot-holes in the chalk could not be ascertained.

The London Clay.—By far the greater part of the tunnels are driven in the London Clay, and mostly in the lower and more

* The water was encountered in this bed. The O.D. surface is 89·5.

sandy portion. Some distance north of Euston Road a slightly higher horizon is reached, but nowhere have the upper beds been penetrated except in shafts or bores near Hampstead Heath.

Here the Bagshot Beds were also passed through 20 feet of sand and gravel being pierced; while the upper beds of the London Clay were proved to be about 150 feet thick.

Thames Valley Deposits.—Shafts and borings show that these deposits occur on the north side of the river for some little distance beyond Euston and Marylebone Road. On the south side they extend far beyond the limit of the area covered by the Tube railways. Only two points of special interest have been noted. The first relates to the water in the gravel on the lower ground near West Kensington. In making the incline from the tunnel at this locality a great quantity of water was encountered in these gravels, below high water mark of the Thames. During the progress of the cutting the workmen often got their hands wetted by this water, and if by any chance their hands were cut or the skin abraded at the time, their arms often swelled up, and they were at times laid off work by blood poisoning. This water appears to rise and fall slightly with the tide of the Thames, showing that it is ponded back by the river. There seems good reason to believe it is the accumulation of years; and is largely composed of the drainage from the higher level gravels, which brought with it the overflow of old cesspits. As the supply of such water has now been entirely stopped by the modern system of sewers and drains it might be advisable to pump this poisonous water out and allow it to be replaced by the inflowing cleaner Thames water. Such work would probably not entail any large or permanent charge.

The second point is more of strictly geological interest. In driving the tunnel under the Thames, near Charing Cross Bridge, it was proved that at one point the Thames Valley Gravels extended to a depth of fully 80 feet below sea level; thus furnishing further evidence of the movement of depression, in comparatively recent times, that has extended over all the southern part at least of the British Isles. Oddly enough the further course eastward of this old deep channel has not yet been traced, the other tunnels having failed to prove anything of the kind. The deep channel obviously must turn abruptly to the south, for the present channel of the Thames, at the east end of London, is shown further on to be of quite recent date.

THE ROTHERHITHE TUNNEL.

At the invitation of the London County Council the plans and workings in connection with the Rotherhithe Tunnel have been inspected from time to time. The resident engineers have not only explained the plans but assisted in the examination of the beds passed through, as well as in collecting a series of illustrative specimens, the latter being forwarded to the museum in Jermyn Street. Considerable additions have thus been made to our know-

ledge of the lithology of the Woolwich and Reading Beds, and a section of the part so far proved is given below.

	Ft.	In.
1. Hard mottled red and green clays (top not proved yet).	16	0
2. Green sands and clays. In this are lenticular patches of shelly marl (*Cyrena*) and of peaty lignite. Oyster bed at base.	15	0
3. Impure limestone (often pebbly).	6	0
4. Sandy marl.	2	0
5. Green sand and pebbles.	4	0
6. Green ballast.	1	0
7. Green sand, base not proved.	5	0

1. The hard mottled Reading clay is identical with that at the top of the group in all the Tube sections. The total thickness will be proved in the subway on the north of the river, which is now in the lower beds of the London Clay and will pass through the junction with the mottled beds.

2. The thickness of the green sands and clays with the *Cyrena* beds and lenticles of peaty lignite varies greatly, for it is found that there is a line of erosion at the base of the mottled clay, so that at times the beds of Group 2 are only 2 or 3 feet thick.

3. The impure limestone band is specially interesting, as on the north side of the river it is 6 feet thick and comparatively free from pebbles. As it is traced across the river the bed thins and becomes pebbly and very hard, then closely resembling the Hertfordshire Pudding-stone. On the south side of the river it is much thinner, and is believed to thin away entirely, being replaced by green marl.

The oyster bed is usually about 4 feet thick, but varies slightly. In the upper part oyster shells (*Ostrea tenera*) are the dominant constituent of the bed, a species of *Aporrhais* occurring more rarely. In the lower part of the bed examples of *Cyrena* are mingled with the *Ostrea* and *Potamides funatus* is also present in considerable numbers. The shells are mixed with a greenish sandy clay or marl, and minute pebbles occur scattered all through. This bed seems to cover a considerable area. An attenuated representative of it occurs in the tunnel close to the Holborn Restaurant.

A small band of Sarsen stone has been met with at the Shadwell end of the tunnel. It is a few feet below the base of the hard mottled clay, and clearly occupies approximately the same horizon as that met with in the Uxbridge area, to be described later. A peculiarity of this rock at Shadwell is that it contains many specimens of *Cyrena cordata*, which are perfectly preserved when the rock is first broken open; unfortunately the shell falls to pieces after a few hours' exposure to the atmosphere.

The identification of the three hard bands in the Woolwich beds is important because the mention of hard bands in well sections in the area about Shadwell is confusing. When only one is present the published accounts make it appear that

there is considerable variation in the thickness of the beds above the chalk. Knowing that it is not necessarily the same band that was met with, and being able to identify the particular band by its associations, it is now seen that the thickness of the lowest Tertiary Beds in this area is singularly constant.

Thames Valley Deposits.—Some interesting points have been noted in the superficial deposits; in the first place a bed of peat 13 feet thick has been met with, the base of which is 17 feet below mean sea-level, again affording clear evidence of comparatively recent subsidence. It attests also the oscillations of the river, for the present stream-bed has been cut through this peat, and is entirely more recent than it—indeed it may fairly be said to be almost of modern date. Further, the borings in the river bed and the driving of the tunnel have proved that the deep channel noted at Charing Cross does not occur here, but must lie considerably to the south.

THE SECTIONS AT GERRARD'S CROSS.

The extensive cuttings on the Great Central Railway near Gerrard's Cross, in the Uxbridge area, afford good sections of the Reading Beds, the base of the London Clay and the overlying Drift deposits. The basal beds of the London Clay here are of the same nature as in the Tube-tunnels. They are markedly sandy, the last few feet being a dark sandy silt. Scattered in this, small fossils are common; they consist chiefly of gasteropods. Quite at the base is a thin band specially rich in a small *Ostrea*, but owing to the acid set free by the decomposition of the marcasite in the clay, these shells are all friable, and specimens cannot be obtained in good preservation.

This shelly band reposes persistently on the top of the Reading Beds, the highest layer of which is a soft green marl. This soon passes down to the type hard mottled red and green marl of the areas already described, and it is clear that this part of the series is peculiarly persistent. About 20 feet of this material is exposed in one section, but the total thickness is nowhere seen, mainly owing to the number of faults present, but partly because the banks are drained and grassed over as soon as possible owing to the tendency of these clays to slip down the face of the cutting. The marl is underlain by pale coloured sands with intercalated red clay bands. In the highest of these sands a lenticular patch of Sarsen stone was met with *in situ*. It passed insensibly into a white sand, and it seems evident that the stone is the sand cemented, rather than that the sand results from the decomposition of the hard rock.

The white sands are succeeded by green sands, in some parts of which the green colour is specially well marked. This part of the series is again identical with that at Rotherhithe, but below this there is a great divergence. The green sand is within a foot or so of the chalk, if not directly on it, and clearly there is no Thanet-sand here.

A little west of the Gerrard's Cross area the cuttings are mainly

in Chalk, but about Picklands Wood there is a constant alternation of Chalk and small patches of the green sands, with the addition in one place of another patch of Sarsen stones. This alternation is clearly due to pot-holes in the chalk letting down the small patches of the Reading Beds; and on the north-west side of the bridge at this wood these holes are so large and close together as to give the overlying Tertiary Beds the aspect of being violently contorted as they sink into and rise out of the holes.

The greater part of the country about Gerrard's Cross is covered with a drift deposit, mainly composed of chalk flints with which a small and very variable amount of clay is irregularly associated. The flint beds are locally divided by beds of sand, fine clay and silt, which are at times continuous for considerable distances. The flints vary greatly in appearance; in some cases very few of them are at all rounded, and then chips of flint are usually abundant. On the other hand beds occur in which the flints are mostly rounded. But in all cases pebbles of liver-coloured quartzite are present in considerable numbers, and as these are *invariably* well rounded, it is most probable that the flints were, so to speak, picked up in much the same state as that in which they now occur; in other words, the chalk flints were rounded before they were incorporated in the drift, and not during the process of formation of the drift deposits, whatever that process may have been. The information obtained from the three sources given above confirms the views arrived at by many previous observers. It is clear that portions of the Tertiary strata change rapidly as they are followed from East to West. While the change is very slight in the case of the London Clay, it is well marked in the Woolwich and Reading Beds; indeed the use of the two names to characterise two types is made clear by the above notes. At Gerrard's Cross to the west, all the shell-bearing bands have either disappeared or are no longer fossiliferous, while the Thanet-sands have thinned away entirely. It is also clear that the rocks of the London Basin are more faulted and disturbed than is commonly supposed. Faults are numerous and many of them are reversed, and it seems a reasonable conclusion that the disturbances of the Purbeck area and of the Hogsback extended northward to the Thames Valley, though acting with far less force.

III.—Supplementary Notes on the Search for Coal Beneath the Red Rocks of the Midland Counties.

By Walcot Gibson, B.Sc., F.G.S., with Appendix by T. C. Cantrill, B.Sc.

Borings.

Claverley.—(Lat. 52° 31′ 7″; Long. 2° 17′ 25″) References to this experimental boring, situated five miles east of Bridgnorth, were given in the Summary for 1904, p. 150. On the com-

pletion of the boring in May, 1905, permission to break up the cores was granted by Mr. Edward Parry. Mr. J. Pringle has made three sets of specimens, one for the Mining Department of Birmingham University, a second for the Survey, and a third for Nottingham University.

This boring must be regarded as one of the most important put down in the Midlands within recent years, since it determines the succession and thickness of the barren Upper Coal-measures in an area remote from coal-workings. The scientific results, which have a considerable economic bearing, have proved of much interest. They may be briefly summarised as follows.

The first 1,240 feet consists of the red rocks of the so-called Permian. A threefold grouping can be made out corresponding to the Upper, Middle and Lower Permian of Prof. Hull, and Mr. Wickham King. The upper group, down to 185 feet depth, consists of red marls, red sandstones, and two thin bands of breccia. The middle group is made up of red sandstones and marls with two well-marked bands of conglomerate, of which the lowest forms the base of the group (at 472 feet depth). The lower group (472 to 1,240 feet depth) consists of purple and lavender-red marls and sandstones. While the boring gives no fossil evidence as to the age of the two superior groups, the following plants, collected by Mr. Pringle and identified by Mr. Kidston, conclusively prove the lower group to be of Coal-measure age:—

Annularia sphenophylloides, *Zenk.* sp.
Calamites sp.
Cordaites borassifolius, *Sternb.* sp.
Lepidodendron sp.
Neuropteris Scheuchzeri, *Hoffm.*
Neuropteris ovata, *Hoffm.*
Neuropteris heterophylla, *Brongn.*
Pecopteris Miltoni, *Artis* sp.
Pecopteris (Cyatheites) sp.
Palæoxyris cf. carbonaria, *Schimp.*
Walchia cf. hypnoides, *Brongn.*

With the exception of *Walchia hypnoides* all these forms occur in the Middle Coal-measures. Bands and nodules of a dark limestone with *Spirorbis* were found at 488, 775, and 972 feet respectively The last band corresponds in position with that discovered by Mr. Cantrill in the neighbourhood of Upper Arley.*

These red rocks pass down, to a depth of 1,604 feet, into grey sandstones and shales with two thin coals. They are the undoubted equivalents of the Halesowen Sandstones of South Staffordshire. Beneath these, to a depth of 1,756 feet the boring passed through variegated chocolate-coloured marls containing the characteristic bands of green Espley rocks. The thickness of 152 feet is much below the average for the district, and a fault may have been passed through.

* *Quart. Journ. Geol. Soc.*, vol. li., p. 528.

The usual grey sandstones, shales and fireclays of the Coal-measures occurred below, down to a depth of 2,190 feet, when Silurian was entered. Mr. Kidston is of opinion that the plants indicate the presence of Lower (Lanarkian) and Middle (Westphalian) Coal-measures.

At 645 feet an igneous rock was penetrated for 25 feet. Mr. Thomas describes this as a fairly coarse-grained olivine dolerite of an intrusive nature, characterised by the presence of titaniferous augite and plentiful analcime. The rock shows affinities with the teschenites.

Langley Green.—(Lat. 52° 19′ 15″, Long. 1° 59′ 40″). The cores of this boring, which is situated on the east side of the South Staffordshire Coalfield, have been examined, permission to do so having been granted by Mr. Henry Johnson. Like Claverley it commenced in the so-called Permians, but here again the following plants identified by Mr. Kidston indicate the Coal-measure age of the lower 684 feet, the upper 200 feet yielding no identifiable fossils:—

Alethopteris aquilina, *Scholth.* sp.
Cordaites borassifolius, *Sternb.* sp.
Neuropteris Scheuchzeri, *Hoffm.*
Neuropteris ovata, *Hoffm.*
Pecopteris arborescens, *Schloth.* sp.
Pecopteris cf. cyathea, *Schloth.* sp.
Walchia piniformis, *Sternb.*

W. GIBSON.

Warwickshire.—In December a visit was paid to the neighbourhood of Coventry and Nuneaton for the purpose of examining some clay-pits in the Coal-measures at Chilvers Coton. As Mr. W. Andrews* has recently pointed out, two open pits there are particularly interesting, in that they have been excavated across the crops of the coals in such a way that in one of the pits six seams and in the other four are exposed in continuous section.

At the same time opportunity was taken to make inquiries with regard to sinkings and borings for coal and water in the so-called Lower Permian rocks of the Warwickshire coalfield. In view of the probability that near Baxterley† these red measures, so far as regards their lowest part, belong to the Coal-measures and are the equivalents of the Keele beds of the Midland coalfields, it becomes of the greatest economic importance that all borings and sinkings through them should be carefully recorded.

T. C. CANTRILL.

* "Recent Progress in Geological and Archæological Investigation in Warwickshire and Neighbourhood.' *Warw. Nat and Arch. Field Club*, April 21, 1904.

† "The Geology of the Country between Atherstone and Charnwood Forest," by C. Fox-Strangways, p. 28 (*Mem. Geol. Survey*).

IV.—Catalogue of Types and Figured Specimens of British LAMELLIBRANCHIATA from the Lower, Middle, and Upper Oolites, preserved in the Museum of Practical Geology, London.

By H. A. Allen, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species or variety. The identity of some few specimens is not quite certain : these are marked [**Doubtful**]. The figures in brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed :—

Ann. Mag. Nat. Hist. : Annals and Magazine of Natural History, London.
"Cotteswold Hills" : "The Cotteswold Hills Hand-book," by J. Lycett, London.
Geol. Mag. : The Geological Magazine, London.
M. G. S. : Memoirs of the Geological Survey of the United Kingdom.
Mon. Pal. Soc. : Monographs of the Palæontographical Society, London :—
"A Monograph of the Mollusca from the Great Oolite," by Prof. Morris and John Lycett, and Supplementary Monograph by John Lycett.
"A Monograph of the British fossil Trigoniæ." by John Lycett.
(The dates quoted refer to year of issue only.)
Proc. Cotteswold Nat. : Proceedings of the Cotteswold Naturalists' Club, London.
Q. J. G. S. : Quarterly Journal of the Geological Society of London.

Inferior Oolite.

Arca rudiuscula, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 424 ; Proc. Cotteswold Nat., vol. I., 1853, p. 85.
Inferior Oolite. [5461] Leckhampton.

Astarte anatiformis, Whidborne. **T.**

G. F. Whidborne, Q.J.G.S., vol. xxxix., 1883, pl. xviii., f. 14, p. 526.
Inferior Oolite. [9138] Nailsworth.

Astarte pontonis, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xl., f. 31, p. 75.
Inferior Oolite. [9137] Ponton, Lincolnshire.

Ceromya bajociana, d'Orbigny.

J. Lycett, "Cotteswold Hills," 1857, pl. v., f. 4 a–b, p. 167.
Inferior Oolite. [9158] Rodborough.

Corbis aspera, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, pl. xi., f. 7 p. 423 ; Proc. Cotteswold Nat., vol. i. 1853, pl. ii, f. 7, p. 84.
Inferior Oolite. [9131] Minchinhampton.

Corbis (Corbicella) complanata, Lycett. **T.**

J. Lycett, "Cotteswold Hills," 1857, pl. vi., f. 1 a, b, p. 128.
Inferior Oolite (*Rh. spinosa* zone). [9147] Rodborough Hill.

Corbis (Corbicella) subœquilatera, Lycett. **T.**

J. Lycett, "Cotteswold Hills," 1857, p. 126.
Inferior Oolite. [9157] Rodborough Hill.

Cucullæa nana, Lycett. **[Doubtful].**

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 425 ; Proc. Cotteswold Nat., vol. i. 1853, p. 86.
Inferior Oolite. [5463] Leckhampton.

Cucullæa obliqua, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. vi. 1850, p. 425 ; Proc. Cotteswold Nat., vol. i, 1853, p. 86.
Inferior Oolite. [5467] Leckhampton.

Cypricardia brevis, Wright.

J. Lycett, "Cotteswold Hills," 1857, pl. i, f. 3 a, b.
Inferior Oolite Sands. [8011] Nailsworth.

Cyprina ?

J. Morris in Hull, M.G.S., "Geol. Cheltenham," 1857, pl. i., f. 5, p. 104.
Inferior Oolite. [9140] Stoney Cockbury.

Cytherea picta, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 423 ; Proc. Cotteswold Nat., vol. i., 1853, p. 84.
Inferior Oolite. [9148] Leckhampton ?

Gervillia aurita, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, pl. xi., f. 4, p. 421 ; Proc. Cotteswold Nat., vol. i., 1853, pl. ii., f. 4, p. 82.
Inferior Oolite. [8862] Nailsworth.

Gervillia compressa, Whidborne. **T.**

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvi., f. 6, p. 517.
Inferior Oolite. [8863] Nailsworth.

Gervillia prælonga, Lycett. **T.**

J. Lycett, "Cotteswold Hills," 1857, pl. vi., f. 6, p. 168.
Inferior Oolite. [8864] Rodborough Hill.

Gresslya abducta, (Phillips).

J. Lycett, "Cotteswold Hills," 1857, pl. v., f. 2a, b, p. 167.
Inferior Oolite (*Rh. spinosa* zone). [9159] Rodborough Hill.

Homomya crassiuscula (M. & L.).

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliii., f. 5, p. 89.
Inferior Oolite. [9161] Cold Comfort.

Homomya gibbosa, Sowerby.

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xliii., f. 2, 2a, p. 88.
Inferior Oolite. [9160] Rodborough Hill.

Hinnites abjectus (Phillips).

J. Lycett, "Cotteswold Hills," 1857, pl. v., f. 5, p. 167.
Inferior Oolite. [8780] Rodborough Hill.

Inoceramus quadratus *vide* **Perna quadrata.**

Isocarca capitalis, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xviii., f. 6, p. 523.
Inferior Oolite. [9069] Rodborough Hill.

Isocarca texata, Muenster.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xviii., f. 7, 7a, p. 523.
Inferior Oolite. [9070] Nailsworth.

Lima educta, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvii., f. 4, 4a, p. 506.
Inferior Oolite (L. *Trigonia* Grit.) [9044] Leckhampton.

Lima inoceramoides, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvii., f. 5., p. 507.
Inferior Oolite. [9045] South of Perrott.

Lima majestica, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvii. f. 6, 6a, b, p. 508.
Inferior Oolite. [9046] Rodborough.

Lima œpybolus, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvii., f. 1, 1a, p. 503.
Inferior Oolite. [9047] Burstock, Broad Windsor.

Lima ornata, Lycett. T.

J. Lycett, "Cotteswold Hills," 1857, pl. i, f. 5, p. 127.
Inferior Oolite Sands. [8009] Frocester Hill.

Lima pectiniformis (Schlotheim).

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxix., f. 1, p. 39.
Inferior Oolite. [9048] Rodborough Hill.

Lima platybolus, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvii., f. 8, 8a, p. 510.
Inferior Oolite. [9054] Nailsworth.

Lima seminuda, Whidborne. ?

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvii., f. 11, 11a, p. 512.
Inferior Oolite. [9053] Nailsworth.

Macrodon ? rapidus, Whidborne. T.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xviii., f. 2, 2a, p. 521.
Inferior Oolite. [9075] Dundry.

Myacites compressiusculus, Lycett. T.

J. Lycett, "Cotteswold Hills," 1857, pl. v., f 1., p. 129.
Inferior Oolite (*Rh. spinosa* zone.) [9162] Nailsworth.

Myoconcha striatula (Goldfuss).

J. Lycett, "Cotteswold Hills," 1857, pl. iii., f. i, p. 166.
Inferior Oolite. [9141] Nailsworth.

Mytilus crenatus, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 421 ; Proc. Cotteswold Nat., vol. i, 1853, p. 82.
Inferior Oolite. [9071] Leckhampton.

Mytilus primipilaris, Whidborne. T.

G. F. Whidborne, Q. J. G. S. vol. xxxix., 1883, pl. xvi., f. 13, 13a, p. 518.
Inferior Oolite. [9072] Stibbington.

Opis carinatus, Wright.

J. Lycett, "Cotteswold Hills," 1857, pl. i., f. 6.
Inferior Oolite Sands. [8012] Frocester Hill.

Opis cordiformis, Lycett. T.

J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 2a, b, c, p. 128.
Inferior Oolite. [9144–9146.] Rodborough Hill.

Opis gibbosus, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 421 ; Proc. Cotteswold Nat. vol. i., 1853, p. 82 ; "Cotteswold Hills," 1857, pl. iii., f. 3, p. 166.
Inferior Oolite. [9143] Leckhampton.

Opis elongatus, Lycett. T.

J. Lycett, "Cotteswold Hills," 1857, pl. iii., f. 3, p. 166.
Inferior Oolite. [9142] Nailsworth.

Pecten cornutus, Quenstedt.

G. F. Whidborne, Q. J. G. S., vol. xxxix., 1883, pl. xvi., f. 1. p. 498.
Inferior Oolite. [8849] Bridport.
G. F. Whidborne, Q.J.G.S., vol. xxxix, 1883, pl. xvi., f. 2, 2a, p. 498.
Inferior Oolite. [8850] Leckhampton.

Pecten symmetricus, Morris. T.

J. Morris in E. Hull, M. G. S., "Geol. Cheltenham," 1857, pl. i, f. 3, 3a–c, p. 103.
Inferior Oolite. [8853] Andoversford.

Perna quadrata, J. de C. Sowerby.

J. Lycett, Ann. Mag. Nat. Hist., vol. xv., 1855, p. 427, figs. 1,2 ; Proc Cotteswold Nat., vol. ii., 1860, p. 118, figs. 1, 2. Refigured as **Inoceramus quadratus**, Mon. Pal. Soc., Suppl. 1863, pl. xxxviii., f. 1, 1*a*, b, p. 38.
Inferior Oolite. [8865–8867] Nailsworth.

Pinna claviformis, Whidborne. T.

G. F. Whidborne, Q.J.G.S., vol. xxxix., 1883, pl. xvi., f. 11., p. 518.
Inferior Oolite. [8868] Selsby Hill, Nailsworth.

Placunopsis sp.

J. W. Judd, Geol. Mag., vol. viii. 1871, pl. ix., f. 2, p. 356.
Inferior Oolite [10,414] Rodborough Hill.

Plicatula complicata (Lycett).

J. Morris in E. Hull, M.G.S., "Geol. Cheltenham," 1857, pl. iii., f. 2, p. 103.
Inferior Oolite (Pea grit). [8779] Cleeve Cloud, Cheltenham.

Ptychomya? Agassizii, Lycett. T.

J. Lycett, Ann, Mag. Nat. Hist. vol. vi., 1850, pl. xi. f. 6, p. 409 ; Proc. Cotteswold Nat., vol. i., 1853, pl. ii., f. 6, p. 69.
Inferior Oolite. [9139] Nailsworth.

Quenstedtia oblita (Phillips).

Morris and Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 4 *a*, *b*, p, 96.
Inferior Oolite. [9149, 9150] Rodborough Hill.
J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 6*a*–*c*, p. 167.
Inferior Oolite. [9151, 9152, 9156.] Rodborough Hill.

Sphæra crassicosta (d'Orbigny).

G. F. Whidborne, Q.J.G.S., vol. xxxix., 1883, pl. xvi., f. 16, 16*a*, p. 526.
Inferior Oolite. [9136] Nailsworth.

Tancredia compressa (Terquem).

J. Lycett, "Cotteswold Hills," 1857, pl. iii., f. 7, p. 167.
Inferior Oolite. [9135] Woodchester Park.

Tancredia donaciformis, Lycett. T.

J. Lycett, Proc. Cotteswold Nat., vol. i., 1853, p. 239 (text-figure); "Cotteswold Hills," 1857, pl. iv., f. 3, 3*a*, p. 167.
Inferior Oolite. [9132] Rodborough Hill.
J. Lycett, Proc. Cotteswold Nat., vol i., 1853, p. 239 (text figures.)
Inferior Oolite. [9133, 9134] Rodborough Hill.

Trichites nodosus, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. v., 1850, pl. x. upper figure, p. 347; Morris and Lycett, Mon. Pal. Soc., 1853, pl. iii., f. 11, p. 35.
J. Lycett, Ann. Mag. Nat. Hist., vol. v., 1850, pl. x. lower figure, p. 347.
Inferior Oolite. [8869, 8870] Nailsworth.

Trichites undatus, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. v., 1850, p. 347.
Inferior Oolite. [8871] Locality?

Trigonia angulata, J. de C. Sowerby.

J. Lycett, Mon. Pal. Soc., 1874, pl. xiv., figs. 5, 6, p. 54.
Inferior Oolite. [9107, 9108] near Stroud.

Trigonia bella, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxii., figs. 6, 7, p. 162.
Inferior Oolite. [11873, 11874] Bradford Abbas.

Trigonia Brodiei, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxv., figs. 8, 9, p. 195.
Northampton Sand. [5470, 11410] Milcomb Hill, Oxfordshire.

Trigonia clavo-costata, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 6, p.235; Proc. Cotteswold Nat., vol. i., pl. ix., f. 6, p. 257.
Inferior Oolite. (See also *T. signata*.) [9089] Nailsworth.

Trigonia compta, Lycett.

J. Lycett, Mon. Pal. Soc., 1874, pl. xv., figs 5–7, p. 70.
Inferior Oolite. [11744–11746] Collyweston.

Trigonia conjungens, Phillips.

J. Lycett, Mon. Pal. Soc., 1874, pl. x., figs. 5–8; pl. xiii., f. 6, p. 62.
Inferior Oolite. (Millepore Bed) [11747–11750] Cloughton, Scarborough.

Trigonia costata, J. Sowerby.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxix., figs. 5–8, p. 147.
Inferior Oolite. [11880–11883] Bradford Abbas.

Trigonia costata, *var.* **lata**, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1875, pl. xxix., f. 9, p. 147.
Inferior Oolite. [11887] Cotteswold Hills
J. Lycett, Mon. Pal. Soc., 1875, pl. xxix., f. 10, p. 147.
Inferior Oolite. [11884] Stroud.

Trigonia costatula, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 5, p. 231; Proc. Cotteswold Nat., vol. i., 1853, pl. ix., f. 5, p. 253; Mon. Pal. Soc. 1874, pl. xv., f. 8, p. 81.
Inferior Oolite. (See also *T. exigua*.) [9079] Rodborough Hill

Trigonia costatula, Lycett.

J. Lycett, Mon. Pal. Soc., 1874, pl. xv., figs 9, 10, p. 81.
Inferior Oolite. [9078, 9080] near Stroud.

Trigonia Culleni, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxi., figs. 9, 9*a*, p. 173.
Inferior Oolite (Millepore Bed). [11885] Cloughton, Scarborough.

Trigonia decorata, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 1, p. 233; Proc. Cotteswold Nat., vol. i., 1853, pl. ix., f. i., p. 255.
Inferior Oolite. [9109] Rodborough Hill.

Trigonia denticulata, Agassiz.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxix., figs. 1–3, p. 152.
Inferior Oolite. [9085–9087] Cloughton, Scarborough.

Trigonia denticulata, Ag., *var.*

J. Lycett, Mon. Pal. Soc., 1877, pl. xxix, f. 4, p. 152.
Inferior Oolite. [9088] South Lincolnshire.

Trigonia duplicata, J. Sowerby.

J. Lycett, Mon. Pal. Soc., 1872, pl. i., f. 8, p. 14.
Inferior Oolite. [9090] Rodborough.
J Lycett, Mon., Pal. Soc., 1872, pl. i., f. 9, p. 14.
Inferior Oolite. [9091] near Yeovil.
J Lycett, Mon. Pal Soc., 1872, pl. i., f. 10, p. 14.
Inferior Oolite. [9092] near Stroud.

Trigonia exigua, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 3, p. 232; Proc. Cotteswold Nat., vol. i., 1853, pl. ix., f. 3, p. 253. Refigured as T. **costatula**, Mon. Pal. Soc., 1874, pl. xii., f. 6, 6*a*, p. 81.
Inferior Oolite. [9081] Leckhampton Hill.

Trigonia formosa, Lycett.

J. Lycett, Mon. Pal. Soc., 1872, pl. v., figs. 4–6; pl. xi. f. 2, p. 35.
Inferior Oolite. [11414–11417] Rodborough Hill, Cheltenham.
J Lycett, Mon. Pal. Soc., 1877, pl. xxxvii., f. 10, p. 35.
Inferior Oolite. [11420] Bradford Abbas.

Trigonia formosa, Lycett, *var.* **lata**, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xxix., f. 11; pl. xxxv., f. 7, p. 202.
Inferior Oolite. [11418, 11419] Bradford Abbas.

Trigonia gemmata, Lycett.

J. Lycett, Mon. Pal. Soc., 1872, pl. i., f. 7, p. 15.
Inferior Oolite. [11401] Cheltenham.

Trigonia hemisphærica, Lycett. **T.**

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 2, p. 231; Proc. Cotteswold Nat., vol. i., 1853, pl. ix., f. 2, p. 252.
Inferior Oolite. [9083] Nailsworth.

Trigonia hemispherica, Lycett.

J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 4, p. 137.
Inferior Oolite. [9084] Rodborough.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxi., figs. 4–8, p. 174.
Inferior Oolite. [11854–11858] Santon Bridge, Appleby, Lincolnsh.

Trigonia hemispherica, *var.* **gregaria**, Lycett. T.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiii., figs. 4–6, p. 174.
Inferior Oolite. [11859–11861] Appleby, Lincolnshire.

Trigonia Phillipsi, M. & L.
J. Lycett, Mon. Pal. Soc., 1872, pl. vi., figs. 3, 4, p. 38.
Inferior Oolite. [11434, 11435] Appleby, Lincolnshire.

Trigonia, producta, Lycett.
J. Lycett, Mon. Pal. Soc., 1874, pl. xiii., figs. 1, 2, p. 60.
Inferior Oolite. [9113, 9114] Rodborough Hill.
J. Lycett, Mon. Pal. Soc., 1874, pl. xiii., figs. 3, 4, p. 60; 1877, pl. xxxvii, figs. 1, 2, p. 208.
Inferior Oolite. [9110–9112] Hook Norton, Oxfordshire.

Trigonia Ramsayii, Wright.
J. Lycett, "Cotteswold Hills," 1857, pl. i., f. 8; Mon. Pal. Soc., 1872, pl. vi., f. 6, p. 49.
Inferior Oolite Sands. [8010] Frocester Hill.

Trigonia recticosta, Lycett. T.
J. Lycett, Mon. Pal. Soc., 1872, pl. i, figs 4–6., p. 16.
Inferior Oolite. [11,398–11,400] Cloughton, Scarborough.

Trigonia sculpta, Lycett. T.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiv, figs. 1, 2, 2*a*, p. 157.
Inferior Oolite. [11894, 11895] near Stroud.

Trigonia sculpta, *var.* **cheltensis**, Lycett. T.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiv., f. 3. p. 157.
Inferior Oolite. [11896] Cotteswold Hills.

Trigonia sharpiana, Lycett. T.
J. Lycett, Mon. Pal. Soc., 1874, pl. xv., f. 11; pl. xvi., figs. 4–6, p. 79.
Inferior Oolite [11853] near Northampton.
J. Lycett. Mon. Pal. Soc., 1874, pl. xvi., f. 3. p. 79.
Inferior Oolite (Dogger) [11846] Blea Wyke.

Trigonia signata, Agassiz.
J. Lycett, Mon. Pal. Soc., 1872, pl. ii., f. 1. p. 29.
Inferior Oolite. [11441] Rodborough Hill, Stroud.
J. Lycett, Mon. Pal. Soc., 1872, pl. ii., f. 2, p. 29.
Inferior Oolite. [11442] Cold Comfort, Cheltenham.
J. Lycett, Mon. Pal. Soc.,1872, pl. ii., f. 3, p. 29.
Inferior Oolite (Grey Limestone) [11443] Cloughton, Scarborough.

Trigonia signata, Ag. *var.* **Zieteni**, Lycett. T.
J. Lycett, Mon. Pal. Soc., App. 1883, pl. i., f. 3, p. 5.
Inferior Oolite. [6513] Cloughton, Scarborough.

Trigonia spinulosa, Young & Bird.
J. Lycett, Mon. Pal. Soc., 1872, pl. iii., figs. 4, 5*a*, *b*, 6, p. 44.
Inferior Oolite (Dogger) [11444–11446] Blea Wyke, Yorkshire.

Trigonia striata, J. Sowerby.
J. Lycett, Mon. Pal. Soc., 1872, pl. v., figs. 6, 7, 8, p. 36.
Inferior Oolite. [11447–11449] Bradford Abbas.

Trigonia subglobosa, M. & L. T.
Morris and Lycett, Mon. Pal. Soc., 1853, pl. v., f. 21, p. 55. J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, p. 240; Mon. Pal. Soc., 1874, pl. xii., f. 10, p. 68.
Inferior Oolite. [9117] Stroud.

Trigonia subglobosa, M. & L.

J. Lycett, Mon. Pal. Soc., 1874, pl. xii., f. 8, p. 68.
Inferior Oolite. [9115] Stroud.
J. Lycett, Mon. Pal. Soc., 1874, pl. xii., f. 9, p. 68.
Inferior Oolite. [9116] Nailsworth.

Trigonia tenuicosta, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 4, 4*a*, p. 230; Proc. Cotteswold Nat., vol. i. 1853, pl. ix., f. 4, 4*a*, p. 252.
Inferior Oolite. [11898] Rodborough Hill.

Trigonia tenuicosta, Lycett.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiii., figs. 7, 9, 9*a*, p. 160.
Inferior Oolite. [11891, 11893] Bradford Abbas.

Trigonia tuberculosa, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 422; vol. xii, 1853, pl. xi., f. 9, p. 235; Proc. Cotteswold Nat., vol. i., 1853, pl. ix., f. 9, p. 257; "Cotteswold Hills," 1857, pl. iii, f. 4, p. 166; Mon. Pal. Soc., 1872, pl. v., f. 10, p. 33.
Inferior Oolite. [9119] Leckhampton Hill.

Trigonia tuberculosa, Lycett.

J. Lycett, Mon. Pal. Soc., 1872, pl. v. f. 9, p. 33.
Inferior Oolite. [9120] Leckhampton Hill.

Trigonia v-costata, Lycett. T.

J. Lycett, Ann. Mag. Nat. Hist., vol. xii., 1853, pl. xi., f. 7, p. 232 "Cotteswold Hills," 1857, pl. vi. f. 5, p. 168; Mon. Pal. Soc., 1874, pl. xv. f. 1, p. 66.
Inferior Oolite. [9118] Rodborough Hill.

Trigonia v-costata, Lycett.

J. Lycett, Mon. Pal. Soc., 1874, pl. xi., f. 7, p. 66.
Inferior Oolite. (Collyweston Slate) [9124] Collyweston.
J. Lycett, Mon. Pal. Soc., 1874, pl. xiii., f. 5, p. 66.
Inferior Oolite. [9125] Cold Comfort, Cheltenham.
J. Lycett, Mon. Pal. Soc., 1874, pl. xv., figs. 2–4, p. 66.
Inferior Oolite (Dogger). [9126–9128] Blue Wyke.

Great Oolite.

Anatina plicatella, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xi., f. 6, 6*a*, p. 118.
Great Oolite. [9904] Minchinhampton.

Anatina undulata (J. de C. Sowerby).

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xi., f. 4, p. 118.
Great Oolite. [9903] Minchinhampton

Anomia æstuarina, Tate. T.

R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 12, p. 349.
Infra-Oxfordian Estuarine. [8621] North Cliffs, Portree.

Arca æmula, Phillips, *var.* **transversa**, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 8, p. 47.
Great Oolite. [9199] Minchinhampton.

Arca Eudesii, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 6, 6*a*, p. 46.
Great Oolite. [10865] Minchinhampton.

Arca Kilverti, M. & L. T.
Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 10, p. 45.
Great Oolite. [9194] Minchinhampton

Arca minuta (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vi., f. 19, p. 48.
Great Oolite. [9196] Minchinhampton.

Arca Prattii, M. & L. T.
Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 3, p. 45.
Great Oolite. [9198] Minchinhampton.

Arca pulchra (J. de C. Sowerby). [Doubtful.]
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vi., f. 6, p. 44.
Great Oolite. [9200] Minchinhampton.

Arca rudis (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 12, p. 44.
Great Oolite. [9195] Minchinhampton.

Arca rugosa M. & L. (*? var. of A. Prattii*).
Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 2, p. 47.
Great Oolite. [9197] Minchinhampton.

Arca tenuitexta, M. & L. T.
Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 9, p. 45.
Great Oolite. [10866] Minchinhampton.

Astarte depressa Goldfuss.
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 11, p. 85.
Great Oolite. [9659] Minchinhampton.

Astarte excavata, J. Sow, *var.* **compressiuscula**, M. & L. T.
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 18, p. 85.
Great Oolite. [9658] Minchinhampton.

Astarte excentrica, M. & L. T.
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 8, p. 83.
Great Oolite. [9661] Minchinhampton.

Astarte fimbriata, Lycett. T.
J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xl., f. 34, p. 77.
Great Oolite. [9663] Minchinhampton.

Astarte pumila, J. de C. Sowerby.
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 13, p. 83.
Great Oolite. [9662] Minchinhampton.

Astarte rotunda, Morris.
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 12, p. 84.
Great Oolite. [9657] Minchinhampton.

Astarte squamula, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 9, p. 82.
Great Oolite. [9660] Minchinhampton.

Avicula clathrata Lycett. T.
J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xl., f. 7, 7*a*, *b*, p. 36.
Great Oolite. [9175] Minchinhampton.

Avicula subcostata (Roemer).
J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xl., f. 24, p. 36.
Great Oolite. [9174] Minchinhampton.

Cardium Buckmani, M. & L. **T.**
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 2, p. 64.
Great Oolite. [9205] Minchinhampton.

Cardium concinnum, M. & L. **T.**
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 7, 7 *b*, p. 65.
Great Oolite. [9201] Minchinhampton.

Cardium pes-bovis, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 4, 4*a*, p. 65.
Great Oolite. [9202] Minchinhampton.

Cardium subtrigonum, M. & L. **T.**
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 3, p. 64.
Great Oolite. [9204] Minchinhampton.

Ceromya concentrica (J. de C. Sowerby).
Morris & Lycett, Mon. Pal. Soc., 1855, pl. x., f. 3*a*, *b*, p. 108 ; J. Lycett, *Ibid.*, Suppl., 1863, pl. xxxv., f. 5.
Great Oolite. [9908, 9909] Minchinhampton.

Ceromya plicata, Agassiz, *var.*
Morris & Lycett, Mon. Pal. Soc., 1855, pl. x., figs. 1*a*, *b*, 2, p. 107.
Great Oolite. [9913, 9914] Minchinhampton.

Ceromya Symondsi, M. & L. **T.**
Morris & Lycett, Mon. Pal. Soc., 1855, pl. x., f. 4*a*, *b*, p. 106.
Great Oolite. [9911–9912] Minchinhampton.

Ceromya undulata, M. & L. **T.**
Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 1*a*, p. 106.
Great Oolite. [9910] Minchinhampton.

Corbis aspera, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 13, 13*a*, p. 70.
Great Oolite. [9130] Minchinhampton.

Corbis (Corbicella) bathonica, M. & L. **T.**
Morris & Lycett, Mon. Pal. Soc., 1855, pl. xiii., f. 14, p. 95.
Great Oolite. [9797] Minchinhampton.

Corbis Lajoyei, d'Archiac.
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 12, 12*a*, p. 69.
Great Oolite. [9567] Minchinhampton.

Corbis Lajoyei, d'Arch. *var.* **cingenda**, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 11, p. 70.
Great Oolite. [9129] Minchinhampton.

Corbis Neptuni, Lycett. **T.**
J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxv., f. 19, p. 59.
Great Oolite. [9210] Minchinhampton.

Corbula Buckmani *vide* **C. involuta.**

Corbula hebridica, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 2*a*, *b*, p. 350.
Infra-Oxfordian. [8624, 8625] Loch Bay, Dunvegan.

Corbula involuta, Goldfuss.
Morris & Lycett, Mon. Pal. Soc. 1855, pl. ix. f. 6, p. 97 ; **C. Buckmani**, J. Lycett, *Ibid.*, Suppl., 1863, pp. 63, 121.
Great Oolite. [9874] Minchinhampton.

Cucullæa concinna, Phillips.

Morris & Lycett, Mon. Pal. Soc. 1853, pl. v. f. 7, p. 50.
Great Oolite. [9465] Minchinhampton.

Cyclas media *vide* **Cyrena Jamesonii.**

Cypricardia bathonica, d'Orbigny.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii, f. 8, 8a–c, p. 75.
Great Oolite. [9705–9707] Minchinhampton.

Cypricardia nuculiformis (Roemer).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii, f. 10*a*, p. 76.
Great Oolite. [9702] Minchinhampton.

Cypricardia rostrata (J. Sow.) *var.* **truncata**, Morris. **T.**

J. Morris in E. Hull, M. G. S., "Geol. Cheltenham," 1857, pl. i., f. 8 *a–c*, p. 104.
Great Oolite. [9768–9708] Windrush Quarry?

Cyprina depressiuscula, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc. 1855, pl. xiii., f. 4, p. 90.
Great Oolite. [9703] Minchinhampton.

Cyprina loweana, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xiii., f. 2, 2*a–c*, p. 88.
Great Oolite. [9709, 9710] Minchinhampton.

Cyprina loweana, *var* **elongata**, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc. 1855, pl. xiii., f. 2*d*., p. 88.
Great Oolite. [9711] Minchinhampton.

Cyrena arata, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 6*a–b*, p. 112.
Estuary Shales. [8637] Loch Staffin, Skye.

Cyrena (Miodon) Brycei, Tate. **T.**

R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 1*a–b*., p. 349.
Infra-Oxfordian Estuarine. [8613, 8614] Locality doubtful.

Cyrena cucullata, Tate. **T.**

R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 10*a–b*., p. 350.
Infra-Oxfordian. [8616] Loch Bay, Dunvegan.

Cyrena Cunninghamii, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 9*a–b*, p. 112.
Estuary Shales. [8641] Loch Staffin, Skye.

Cyrena Jamesonii, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., figs. 7*a*, *b*, 8*a*, *b*, p. 111. Referred to **Cyclas media**. R. I. Murchison, Trans. Geol. Soc., Ser. 2, vol. ii., 1829, p. 366.

Estuary Shales. [8639, 8640] Loch Staffin, Skye.

Cyrena MacCullochii, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 10*a–b*, p. 112.
Estuary Shales. [8642] Loch Staffin, Skye.

Gervillia crassicosta, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ii., f. 9, p. 23.
Great Oolite. [9177] Minchinhampton.

Gervillia islipensis, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xl., f. 35, p. 37.
Great Oolite. [9179] Stonesfield.

Gervillia monotis, J. A. E. Deslongchamps.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ii., f. 14, 14*b*, p. 22.
Great Oolite. [9178] Minchinhampton.

Gervillia ornata, Lycett. **T.**

J. Lycett, Mon. Pal., Soc., Suppl., 1863, pl. xxxvi., f. 7, p. 111.
Great Oolite. [9176] Minchinhampton.

Gervillia ovata (J. de C. Sowerby).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ii., f. 12, 12*a*, p. 22.
Great Oolite. [9180] Minchinhampton.

Gervillia subcylindrica, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iii., f. 13, 13*a*, p. 21.
Great Oolite. [9181, 9182] Minchinhampton.

Goniomya litterata (J. Sowerby).

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xi., f. 3, p. 119.
Great Oolite. [10058] Minchinhampton.

Hinnites abjectus, Phillips.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ix., f. 7, p. 125.
Great Oolite. [8851] Minchinhampton.

Hinnites tegulatus, Lycett. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ii., f. 3, 3*a*, p. 14.
Great Oolite. [8851] Minchinhampton.

Homomya Vezelayi *vide* **Myacites.**

Isocardia tenera, J. Sowerby.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii., f. 1, 1*a*, p. 66.
Great Oolite. [9795] Minchinhampton.

Lima gibbosa, J. Sowerby.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iii., f. 7, 7*a*, p. 28.
Great Oolite. [10857] Minchinhampton.

Lima ovalis (J. Sowerby).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iii., f. 5, 5*a*, p. 29.
Great Oolite. [10856] Minchinhampton.

Lima punctatilla, Lycett.

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xl., f. 32, p. 41.
Great Oolite. [10854] Minchinhampton.

Lima semicircularis, Goldfuss.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iii., f. 3, 3*a*, p. 29.
Great Oolite. [10855] Minchinhampton.

Limopsis oolitica (d'Archiac).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 16, p. 54.
Great Oolite. [9464] Minchinhampton.

Lithodomus inclusus (Phillips).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 13, 13*a*, p. 43.
Great Oolite. [10858] Minchinhampton.

Lithodomus parasiticus (J. A. E. Deslongchamps).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 15, 15*a*, p. 43.
Great Oolite. [10859] Hampton Cliff, Bath.

Lucina Bellona, d'Orb., *var.* **depressa,** M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vi., f. 15, p. 67.
Great Oolite. [9207] Minchinhampton.

Lucina despecta, Phillips, *var.* **cardioides,** D'Archiac.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vi., f. 17, p. 69.
Great Oolite. [9209] Minchinhampton.

Lucina rotundata (Roemer).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vi., f. 14, p. 68.
Great Oolite. [9208] Minchinhampton.

Macrodon hirsonensis (d'Archiac).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., figs. 1, 1*a*, *b*, p. 49.
Great Oolite. [9330–9333] Minchinhampton.

Myacites compressus, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xii., f. 11, p. 116.
Great Oolite. [10057] Minchinhampton.

Myacites terquemea (Buvignier).

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xii., f. 6, p. 115.
Great Oolite. [10054] Minchinhampton.

Myacites tumidus, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 2*a*, *b*, p. 117.
Great Oolite. [10056] Minchinhampton.

Myacites unioniformis, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1855, pl. x., f. 6, p. 115.
Great Oolite. [10055] Minchinhampton.

Myacites Vezelayi (Lajoye).

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xi., f. 5, 5*a*, p. 111; **Homomya Vezelayi,** J. Lycett, *Ibid.* Suppl., 1863, p. 89.
Great Oolite [9915] Minchinhampton.

Myoconcha crassa, J. de C. Sowerby.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 16*a*, p. 76.
Great Oolite. [9798] Minchinhampton.

Myoconcha elongata, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 18, p. 77.
Great Oolite. [9796] Minchinhampton.

Mytilus furcatus, Goldfuss, *var.* **bathonicus,** M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 9, 9*a*, p. 39.
Great Oolite. [10863, 10864] Minchinhampton.

Mytilus imbricatus (J. Sowerby).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 2, p. 41.
Great Oolite. [10860] Minchinhampton.

Mytilus pulcherrimus (Roemer) *var.*

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 12, 12*a*, p. 38.
Great Oolite. [10861] Minchinhampton.

Mytilus solenoides, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. iv., f. 4, p. 38.
Great Oolite. [10862] Minchinhampton.

Mytilus ? *vide* **Perna Murchisonii.**

Neæra Ibbetsoni, Morris.

Morris & Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxv., f. 8, 8*a*.
Description in Part II., 1855, p. 98.
Great Oolite. [9875] Kirtlington.

Nucula variabilis, J. de C. Sowerby.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 13, 13*a*, p. 51.
Great Oolite. [10,063, 10,064] Minchinhampton.

Nucula Waltoni, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 14, p. 52.
Great Oolite. [10,061] Minchinhampton.

Opis Deshayesii, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1855, pl. vi., f. 5*a*, p. 81.
Great Oolite. [9792] Minchinhampton.

Opis lunulatus (J. Sowerby) *var.*

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vi., f. 3, 3*a*, p. 80.
Great Oolite. [9793, 9794] Minchinhampton.

Opis similis (J. Sowerby)

Morris & Lycett, Mon. Pal. Soc., 1855, pl. vi., f. 4, 4*a*, p. 81.
Great Oolite. [9791] Minchinhampton.

Ostrea gregaria, J. Sowerby, *var.*

Morris & Lycett, Mon. Pal. Soc. 1853, pl. i, f. 2, 2*a*, p. 4.
Great Oolite. [9165] Minchinhampton.

Ostrea hebridica, Forbes.

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 4*a–c*, p. 110. Referred to **Ostrea**, R. I. Murchison, Trans. Geol. Soc., Ser. 2, vol. ii., 1829, p. 366.
Estuary Shales. [8633–8635 [Loch Staffin, Skye.

Pachyrisma grande, M. & L. **T.**

Morris & Lycett, Q. J. G. S., vol. vi., 1850, p. 399 (Text-figures); Mon. Pal. Soc., 1853, pl. viii., f. 1–5, p. 79.
Great Oolite. [9799–9801] Minchinhampton.

Pecten arcuatus, J. Sowerby.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 18, p. 11.
Great Oolite. [9167] Minchinhampton.

Pecten clathratus, Roemer.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 19, 19*a*, p. 13.
Great Oolite. [9172] Minchinhampton.

Pecten hemicostatus, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc. 1853, pl. i., f. 16, p. 10.
Great Oolite. [9168] Minchinhampton.

Pecten peregrinus, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 14, p. 9.
Great Oolite. [9170] Minchinhampton.

Pecten retiferus, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 15, 15*a*, p. 9.
Great Oolite. [9169] Minchinhampton.

Pecten vagans, J. de C. Sowerby.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 12, 12*a*, p. 8.
Great Oolite. [9171] Minchinhampton.

Pecten Woodwardii, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 20, p. 8.
Great Oolite. [9173] Minchinhampton.

Perna foliacea, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxvii., f. 3, 3*a*, p. 38.
Great Oolite. [9183, 9184] Minchinhampton.

Perna Murchisoni, Forbes. **T.**

E. Forbes, Q. J. G. S. vol., vii., 1851, pl. v., f. 1*a–c*, p. 111. Referred to **Mytilus**? R. I. Murchison, Trans. Geol. Soc., Ser. 2, vol. ii., 1829, p. 366.
Estuary Shales. [8628, 8629] Loch Staffin, Skye.

Pholadomya socialis, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc. 1855, pl. xi., f. 7, 7*a*, p. 122.
Great Oolite. [9905] Minchinhampton.

Pholas oolitica, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 21, p. 126.
Great Oolite. [10,062] Minchinhampton.

Placunopsis jurensis (Roemer).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 8, 8*a*, *b*, p. 6.
Great Oolite. [9187, 9188, 9192] Minchinhampton.

Placunopsis radians, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 10, p. 7.
Great Oolite. [9189] Minchinhampton.

Placunopsis socialis, M. & L. **[Doubtful]**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. i., f. 9, 9*a*, p. 7.
Great Oolite. [9190] Minchinhampton.

Plicatula fistulosa, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ii., f. 5, p. 15.
Great Oolite. [9166] Minchinhampton.

Potamomya robusta, Tate. **T.**

R. Tate, Q. J. G. S., vol. xxix., 1873, pl. xii., f. 11*a*, *b*, p. 350.
Infra-Oxfordian. [8619] Loch Bay, Dunvegan.

Potamomya? Sedgwickii, Forbes. **T.**

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 3*a*, *b*, p. 113.
Estuary Shales. [8631, 8632] Loch Staffin, Skye.

Potamomya? Sowerbii. **T.**

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 2*a*, *b*, p. 112.
Estuary Shales. (See also *Unio.*) [8630] Loch Staffin, Skye.

Pteroperna costatula (J. A. E. Deslongchamps).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. ii., figs, 8, 8*a*, 13*a*, p. 18,
Great Oolite. [9191, 9185] Minchinhampton.

Pteroperna emarginata, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc. 1858, pl. ii., f. 10, p. 19.
Great Oolite. [9186] Minchinhampton.

Quenstedtia oblita (Phillips) *var.*

Morris & Lycett, Mon. Pal. Soc., 1855, pl. ix., f. 4, p. 96.
Great Oolite. [9825] Minchinhampton.

Sowerbya Woodwardi, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl. 1863, pl. xl., f. 27, 27*a–c*, p. 67.
Great Oolite. [9872, 9873] Minchinhampton?

Sphæra madridi (d'Archiac).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. vii, f. 14, 14*a–d*, p. 71.
Great Oolite. [9563–9566] Minchinhampton.

Tancredia axiniformis (Phillips).

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xiii., f. 6*b*, p. 93; **T. extensa.** J. Lycett, *ibid.* Suppl., 1863, p. 120.
Great Oolite. [9556] Minchinhampton.

Tancredia curtansata (Phillips).

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xiii., f. 7*a,b*, p. 93; **T. subcurtansata**, J. Lycett, *ibid.* Suppl. 1863, p. 120.
Great Oolite. [9557–9559] Minchinhampton.

Tancredia extensa *vide* **T. axiniformis.**

Tancredia gibbosa, J. Lycett. **T.**

J. Lycett, "Cotteswold Hills," 1857, pl. vii., f. 4, p. 168; Mon. Pal. Soc. Suppl., 1863, pl. xxxv., f. 7, p. 68.
Great Oolite. [9562] Minchinhampton.

Tancredia planata, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xiii., f. 10*b*, p. 94.
Great Oolite. [9560] Minchinhampton.

Tancredia similis, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxv., f. 9, p. 68.
Great Oolite. [9561] Kirtlington.

Tancredia subcurtansata *vide* **T. curtansata.**

Thracia amygdaloidea, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlii., f. 4, p. 80.
Great Oolite. [10060] Minchinhampton.

Thracia curtansata, M. & L. **T.**

Morris & Lycett, Mon. Pal. Soc., 1855, pl. xiii., f. 1*a, b*, p. 110.
Great Oolite. [10059] Minchinhampton.

Trigonia Clytia, d'Orbigny.

J. Lycett, Mon. Pal. Soc., 1874, pl. xi.. figs. 4, 5; pl. xvii., f. 7, p. 76.
Great Oolite. [9218–9220] Box, near Bath.

Trigonia costata, J. Sowerby, *var.* **pullus**, J. Sowerby. **T.**

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 22, 22*a*, p. 58.
Great Oolite. (See also *T. pullus.*) [9212, 9289] Minchinhampton.

Trigonia flecta, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1874, pl. xiv., figs 7–10, p. 55.
Great Oolite. [10101–10104] Thornholm, Appleby.

Trigonia Goldfussi, Agassiz.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. v., f. 18, p. 56.
Great Oolite. (See also *T. Painei.*) [9213] Minchinhampton

Trigonia imbricata, J. de C. Sowerby.

J. Lycett, Mon. Pal. Soc., 1872, pl. vi., f. 5*a*, *b*, p. 33.
Great Oolite. [9222] Bath.

Trigonia impressa, J. Sowerby.

J. Lycett, "Cotteswold Hills," 1857, pl. vii., f. 5, p. 168 ; Mon. Pal. Soc., 1872, pl. vii., f. 4, p. 46.
Stonesfield Slate. [9164] Stonesfield.
J. Lycett, Mon. Pal. Soc., 1872, pl. vii., f. 5. p. 46.
Stonesfield Slate. [9163] Stonesfield.

Trigonia Moretoni, M. & L.

J. Lycett, Mon. Pal. Soc., 1872, pl. ii., f. 8, p. 47.
Great Oolite. [9221] Bisley Common, Stroud.

Trigonia Painei, Lycett. T.

J. Lycett, Pal. Mon. Soc., 1874, pl. xii., figs. 2, 3, p. 59.
Great Oolite. [9295, 9296] Minchinhampton.
J. Lycett, Mon. Pal. Soc., 1874, pl. xii., figs 4, 5, p. 59.
Great Oolite. (See also *T. Goldfussi.*) [9217, 9294] South Lincolnshire.

Trigonia pullus, J. de C. Sowerby.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiv., figs. 8, 9, p. 164.
Great Oolite. [9288, 9214.] Minchinhampton.

Trigonia tripartita, Forbes. T.

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 11*a*, *b*, p. 111.
Estuary Shales. [8643, 8644] Loch Staffin, Skye.

Trigonia undulata, Fromherz, *var.* **arata**, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1874, pl. xvi., figs. 9–11, pp. 77, 200.
Great Oolite. [9297–9299] Bourn, Lincolnshire.
J. Lycett, Mon. Pal. Soc., 1874, pl. xvii., figs. 5, 6, pp. 77, 200.
Great Oolite. [9216, 9215] South Lincolnshire.

Unicardium impressum, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. viii., f. 9*a*, *b*, *c*, p. 73.
Great Oolite. [9667–9669] Minchinhampton.

Unicardium parvulum, M. & L. T.

Morris & Lycett, Mon. Pal. Soc., 1853, pl. viii. f. 6, 6*a*, p. 74.
Great Oolite. [9665, 9666] Minchinhampton Common.

Unicardium varicosum, (J. Sowerby).

Morris & Lycett, Mon. Pal. Soc., 1853, pl. viii., f. 7, 7*a*, p. 73.
Great Oolite. [9664] Minchinhampton.

Unio ? staffinensis, Forbes.

E. Forbes, Q. J. G. S., vol. vii., 1851, pl. v., f. 5*a*, *b*, p. 111.
Estuary Shales. [8636] Loch Staffin, Skye.

Unio or **Anodon**, "Bivalve referrible to," *vide* **Potamomya ? Sowerbii.**

CORNBRASH.

Astarte Leckenbyi (Wright MS.), Lycett. T.

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlii., f. 3, p. 74.
Cornbrash. [10654] Scarborough.

Lima rigidula (Phillips).

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxiii., f. 7, 7*a*, p. 42.
Cornbrash. [10534] Scarborough.

Ostrea.

J. W. Judd, Geol. Mag., vol. viii., 1871, pl. ix., f. 5*a–c*, p. 357.
Cornbrash. [10415, 10416] Peterborough.

Pholadomya Phillipsi, Morris.

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xlii., f. 2, 2*a*, p. 85.
Cornbrash. [9876] Scarborough.

Placunopsis semistriatus (Bean).

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxiii., f. 9, 9*a*, p. 30.
Cornbrash. [10533] Yorkshire.

Trigonia Cassiope, d'Orbigny.

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxvii., f. 10, p. 49.
Cornbrash. [11886] Scarborough.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxii., figs. 1–5, p. 170.
Cornbrash. [11875–11879] Scarborough.

Trigonia detrita, Terquem & Jourdy.

J. Lycett, Mon. Pal. Soc., 1874, pl. x., f. 4, p. 75.
Cornbrash. [10106] Hilperton.

Trigonia elongata, *var.* **angustata**, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xxx., figs. 1, 1*a*, 2, p. 154.
Cornbrash. [11865–11867] Scarborough.

Trigonia elongata, J. Sow., *var.* **lata**, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xxx., f. 4, p. 154.
Cornbrash. [11868] South Lincolnshire.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxx., f. 5, p. 154.
Cornbrash. [11869] Scarborough.

Trigonia Moretoni, M. & L.

J. Lycett, Mon. Pal. Soc., 1872, pl. ii., figs. 4, 5, 7; pl. iv., f. 6, p. 47.
Cornbrash [9290–9293] Appleby, Lincolnshire.

Trigonia pullus, J. de C. Sowerby.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiv., f. 7, 7*a*, p. 164.
Cornbrash. [9287] Hilperton, Wilts.

Trigonia scarburgensis, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxvii., f. 1, p. 48.
Cornbrash. [10610] Yorkshire.

Trigonia scarburgensis, Lycett.

J. Lycett, Mon. Pal. Soc., 1872, pl. iv., figs. 1–4, p. 31.
Cornbrash. [10612–10614] Scarborough.

Trigonia sculpta, Lycett, *var.* **Rolandi**, Lycett. **T.**

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiv., f. 4, p. 157.
Cornbrash. [11897] Appleby, Lincolnshire.

BRADFORD CLAY AND FOREST MARBLE.

Corbula Agatha, d'Orbigny.

J. Lycett, Mon. Pal. Soc., Suppl. 1863, pl. xl., f. 28, 28a p. 65.
Forest Marble. [10290] Cirencester.

Corbula hulliana, Morris. T.

J. Morris in E. Hull, M.G.S., "Geol. Cheltenham," 1857, pl. i. f. 6, p. 104.
Forest Marble. [9153–9155] Northleach.

Corbula islipensis, Lycett. T.

J. Lycett, Mon. Pal. Soc., Suppl., 1863, pl. xxxvii, f. 7, p. 63.
Bradford Clay. [10065] Islip, Oxon.

Trigonia flecta, Lycett.

Morris and Lycett, Mon. Pal. Soc., 1853, pl. v., f. 20, p. 60.
Forest Marble. [10105] Tetbury Road Station, Cirencester.

KELLAWAYS ROCK AND OXFORD CLAY.

Pholadomya Murchisoni, J. de C. Sowerby. T.

Mineral Conchology, vol. vi., 1827, pl. 545, figs. 1, 2, p. 87.
Kellaways Rock. [11359, 11360] Brora.

Trigonia elongata, J. Sowerby.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxx., figs. 3, 3a–b, 6, p. 154.
Oxford Clay. [11863, 11864] Weymouth.

Trigonia paucicosta, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1874, pl. xi., figs. 8, 9; pl. xvi., f. 7. p. 57.
Kellaways Rock. [11736–11738] Cayton Bay, Scarborough.

Trigonia paucicosta, Lycett.

J. Lycett, Mon. Pal. Soc., 1874, pl. xxxvii., f. 3, p. 57.
Kellaways Rock. [11739] Scarborough.

Trigonia rupellensis, d'Orbigny.

J. Lycett, Mon. Pal. Soc., 1877, pl. xxxvi, figs. 1–4, p. 28.
Kellaways Rock. [11436–11439] Cayton Bay, Scarborough.

Trigonia Williamsoni, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1874, pl. xvi., f. 8; pl. xxxviii, f. 7, p. 53.
Kellaways Rock. [11455–11456] Cayton Bay, Scarborough.

CORALLIAN.

Ostrea discoidea (Seeley MS.), H. B. Woodward, M. G. S. Jurassic Rocks of Britain, vol. v., 1895, p. 136. (Text-figure only). Described F. L. Kitchin, Q. J. G. S., vol. lix., 1903, p. 378.
Ampthill Clay. [11381] Railway Cutting, Ampthill.

Trigonia Bronnii, Agassiz.

J. Lycett, Mon. Pal. Soc., 1872, pl. iv., f. 8, p. 23. Referred to **T. clavellata**, *Ibid.*, 1879, p. 209.
Lower Calcareous Grit. [11413] Weymouth.

Trigonia clavellata, J. Sowerby.

J Lycett, Mon. Pal. Soc., 1872, pl. i., figs. 1, 2, p. 18.
Lower Calc. Grit. (See also *T. Bronnii*). [11411, 11412] Weymouth.

Trigonia corallina, d'Orbigny.

J. Lycett, Mon. Pal. Soc., 1872, pl. iii., figs. 8, 9, p. 45.
Coralline Oolite. [11382, 11383] Steeple Ashton.
J. Lycett, Mon. Pal. Soc., 1872, pl. iii., f. 7; pl. viii., f. 5 p. 45.
Coralline Oolite. [11384, 11385] Pickering.

Trigonia geographica, Agassiz.
J. Lycett, Mon. Pal. Soc., 1874, pl. x., f. 6 ; pl. xxxii., f. 9, p. 69.
Coralline Oolite. [11751, 11752] Pickering.

Trigonia Joassi, Lycett. **T.**
J. Lycett, Mon. Pal. Soc., 1874, pl. xx., f. 2, p. 82.
Lower Calcareous Grit. [11740] Brora, Sutherland.

Trigonia Meriani, Agassiz.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiii., figs. 1, 2, p. 167.
Coralline Oolite. [11870, 11871] Pickering.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxiii., f. 3, p. 167.
Calcareous Grit. [11872] Weymouth.

Trigonia perlata, Agassiz.
J. Lycett, Mon. Pal. Soc., 1872, pl. iii., figs. 1, 3, p. 22.
Coralline Oolite. [11432, 11433] Pickering.

Trigonia triquetra, Seebach.
J. Lycett, Mon. Pal. Soc., 1872, pl. vi., figs. 1*a*, *b*, 2 ; 1877, pl. xxxvi., f. 7, p. 26.
Lower Calcareous Grit. [11450–11452] Filey Point, Yorkshire.

KIMERIDGE, PORTLAND, AND PURBECK BEDS.

Trigonia alina *vide* **T. incurva.**

Trigonia incurva, Benett.
J. Lycett, Mon. Pal. Soc., 1872, pl. ix., f. 2, p. 42. Corrected to **T. alina**, Contejean, *var. Ibid.*, 1877, p. 193.
Kimeridge Clay. [11431] Dorsetshire.
J. Lycett, Mon. Pal. Soc., 1872, pl. ix., f. 3, p. 42.
Portland Oolite. [11421] Swindon.
J. Lycett, Mon. Pal. Soc., 1872, pl. ix., f. 4, p. 42.
Kimeridge Clay. [11422] Wotton Basset, Wiltshire.

Trigonia irregularis, Seebach.
J. Lycett, Mon. Pal. Soc., 1872, pl. v., f. 1*a*, *b*, p. 39.
Oxford Clay. [11423] Weymouth.
J. Lycett, Mon. Pal. Soc., 1872, pl. xxxix., f. 3, p. 39.
Kimeridge Clay. [11424] Wotton Basset.

Trigonia juddiana, J. Lycett. **T.**
J. Lycett, Mon. Pal. Soc., 1872, pl. ii., f. 6*a–c* ; pl. iv., figs. 5, 7, p. 25.
Kimeridge Clay. [11425–11427] Market Rasen, Lincolnshire.

Trigonia monilifera, Agassiz.
J. Lycett, Mon. Pal. Soc., 1877, pl. xxxi., figs. 1, 1*a–b*., 2, 2*a*, 3, p. 165.
Kimeridge Clay. [11888–11890] Weymouth.

Trigonia Pellati, Munier-Chalmas.
J. Lycett, Mon. Pal. Soc., 1872, pl. vii., figs. 1, 2*a*, *b*, p. 41
Kimeridge Clay. [11428–11429] Kimeridge.
J. Lycett, Mon. Pal. Soc., 1872, pl. xi., f. 1, p. 41.
Kimeridge Clay. [11430] St. Ives.

Trigonia Voltzii, Agassiz.
J. Lycett, Mon. Pal. Soc., 1872, pl. x., figs. 1, 2, p. 20.
Kimeridge Clay. [11453–11454] near Weymouth.

Trigonia Woodwardi, Lycett. **T.**
J. Lycett, Mon. Pal. Soc., 1872, pl. xvii., f. 1, p. 40.
Kimeridge Clay. [11440] Dorsetshire.

Trigonia Carrei, Munier-Chalmas.

J. Lycett, Mon. Pal. Soc., 1874, pl. xii., f. 1, p. 72.
Portland Beds. [11743] Tisbury, Wilts.

Trigonia cymba, Contejean.

J. Lycett, Mon. Pal. Soc., Addenda, 1877, pl. xxxviii., f. 1, p. 193.
Portland Sand. [11899] Kimeridge Bay, Dorset.

Trigonia damoniana, de Loriol.

J. Lycett, Mon. Pal. Soc., 1874, pl. xviii., f. 3; 1875, pl. xxi., figs. 3–5, p. 88.
Portland Oolite. [11827–11830] Portland.
J. Lycett, Mon. Pal. Soc., 1874, pl. xix, f. 1*a*–*b*; pl. xxi, f. 2, p. 88.
Portland Oolite. [11831–11832] Swindon.

Trigonia gibbosa, J. Sowerby.

J. Lycett, Mon. Pal. Soc., 1874, pl. xviii., figs, 1, 4, 5, 6; pl. xix., f. 2; pl. xxi., f. 1, p. 84.
Portland Beds. [11833, 11838] Tisbury.

Trigonia Manseli, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1874, pl. xix., figs, 3, 4, 4*a*, *b*, p. 86.
Portland Beds. [11843, 11844] Portland.

Trigonia Michelotti, de Loriol & Pellat. *var.*

J. Lycett, Mon. Pal. Soc., 1874, pl. xx., f. 7, p. 92. (cast)
Portland Beds. [11826] near Devizes.

Trigonia muricata, Goldfuss.

J. Lycett, Mon. Pal. Soc., 1872, pl. ix., f. 1, p. 50.
Portland Beds. [11862] St. Aldhelms Head.

Trigonia tenuitexta, Lycett. T.

J. Lycett, Mon. Pal. Soc., 1874, pl. xx., f. 1, p. 90.
Portland Beds. [11,845] Portland.
J. Lycett, Mon. Pal. Soc., 1874, pl. xx., f. 1, 1*a*, p. 90. (Casts.)
Portland Beds. [11,851, 11,852] Crookwood, Devizes.

Trigonia densinoda, Etheridge. T.

R. Etheridge, Q. J. G. S., vol. xxxvii., 1881, p. 246.
Middle Purbeck. [11,900] Vale of Wardour.

The following lists of British type-fossils have been published in the "Summary of Progress," and *issued* in the years stated:—

Eocene and Oligocene	1900.
Pliocene, Pleistocene, and Devonian	1901.
Phyllocarida and Palæozoic Echinodermata	1902.
Rhætic, Lias, and Inferior Oolite Gasteropoda	1903.
Great Oolite, Cornbrash, and Corallian Gasteropoda	1904.
Rhætic and Lias Lamellibranchiata	1905.

V.—Water Supply of Filey, Yorkshire.

Since the publication of the Memoir on the Water Supply of the East Riding of Yorkshire (1906), attention has been called by Mr. Henry Tobey, Engineer of the Filey Water Works, to the publication on page 145 of that Memoir, of the old analyses of well-water, 1878, given on the authority of G. W. Wigner. From the date of the analyses they must be regarded as simply of historic interest.

The water supplied to the town is derived from the boring at the Gas Works (recorded page 34), and an analysis communicated by Mr. Tobey was inserted (page 164). Unfortunately it was not stated that this was the town supply. It may be further mentioned that the water rises in the well (constructed over the bore-hole) to 60 feet above sea-level, and to about the same distance below ground-level.

Filey, as pointed out to us by Mr. Tobey, had a public water-supply as long ago as 1856, and the public supply at the date of the analyses made in 1878, was by gravitation from Hunmanby Moor, on land lying to the east of the North Eastern Railway, and south of the Reighton and Hunmanby Road.

ANALYSES OF FILEY WATER.

1. Analysis of water from the bore-hole near North Eastern Railway Station, Filey, made by Mr. Thos. Fairley, of Leeds, December, 1905, for the Filey Urban District Council.

Colour, two feet depth	Faint yellow.
Smell	Faint earthy.
	Grains per gallon = parts per 70,000.
Chlorides equal to common salt	8·20
Nitrates, calcium nitrate	None.
Nitrites	None.
Phosphates	None.
Calcium and magnesium carbonates	17·57
Calcium sulphate	4·35
Volatile and organic matter	1·22
Total dissolved solids	31·34
Lead	None.
Hardness	17·5°
„ after boiling	2·5°
Ammonia, grains per gallon	0·010
„ organic, grains per gallon	0·003
Sediment	Very small.
Microscopic examination	No animalculæ.
Micro-organisms per c. centimetre	10 colonies.
„ „ character	Moulds, non-pathogenic

The water is of good quality and suitable for town's supply.

The Chlorides are unusually high, but are most probably of purely mineral origin.

N.B.—This water was not filtered.

2. Analysis of water from High Rosdale, Hunmanby Moor, December, 1905, made by Mr. Thomas Fairley, Leeds, December, 1905, for the Filey Urban Council.

Colour, two feet in depth	Faint bluish green
Smell	Faint earthy.
	Grains per gallon = parts per 70,000.
Chlorides equal to common salt	3·69
Nitrates, calcium nitrate	0·78
Nitrites	None.
Phosphates	None.
Calcium and magnesium carbonates	15·18
Calcium sulphate	3·85
Volatile and organic matter	1·37
Total dissolved solids	24·87
Lead	None.
Hardness	13·3°
„ after boiling	4·9°
Ammonia, grains per gallon	0·001
„ organic „	0·003
Sediment	Very small, peaty matter.
Microscopic examination	A few animalculæ.
Micro-organisms per c. centimetre	24 colonies.

The water is of good quality for drinking and for purposes of town's supply.

N.B.—This water was not filtered.

H. Tobey.

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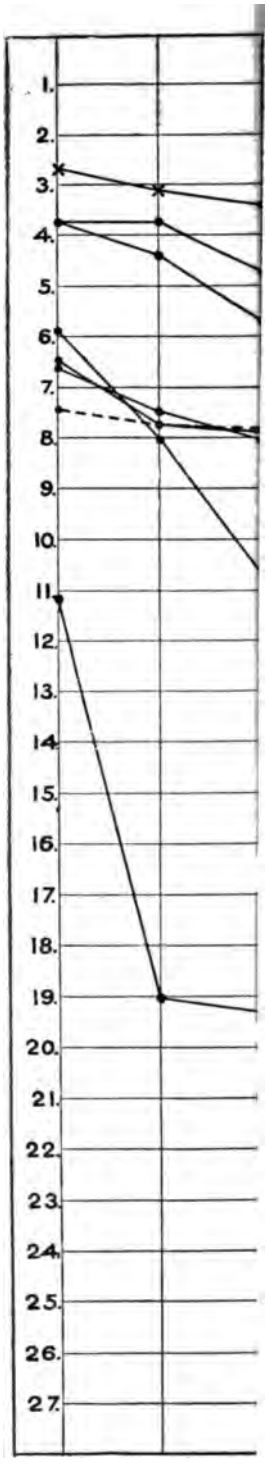

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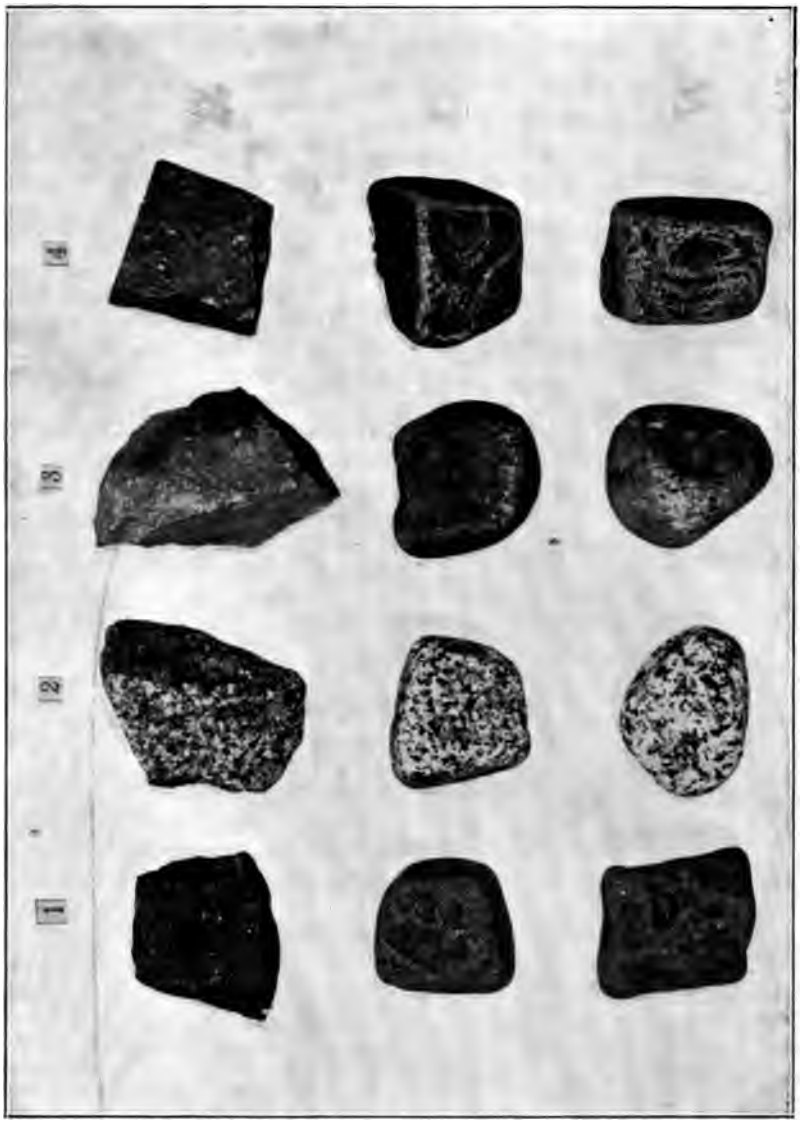

R D W

PHOTOGRAPH OF FOUR ROAD STONES TO SHOW THEIR APPEARANCE AFTER UNDERGOING THE ATTRITION TEST.

R = The rough stone. D = The result after the dry test.
W = The result after the wet test.
1 = A Porphyrite. 2 = A Granite. 3 = An Iron Slag. 4 = A Hornfels.

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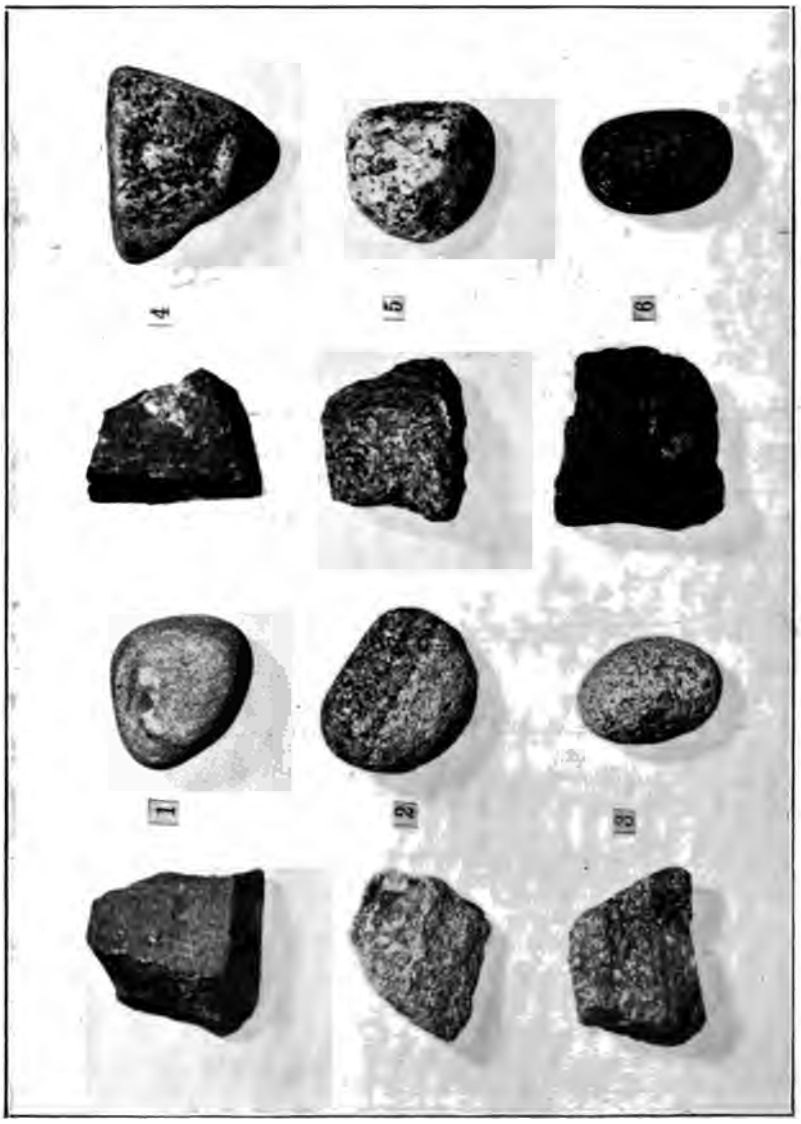
PLATE III.



PHOTOGRAPH OF ROAD STONES TO ILLUSTRATE CASES OF WEAR AFTER UNDERGOING THE ATTRITION TEST.

R = The rough stone. W = The result after the wet test. 1–3 = Sandstones.
4 = A good Diabase. 5 = A coarse Granite. 6 = A poor Dolerite.

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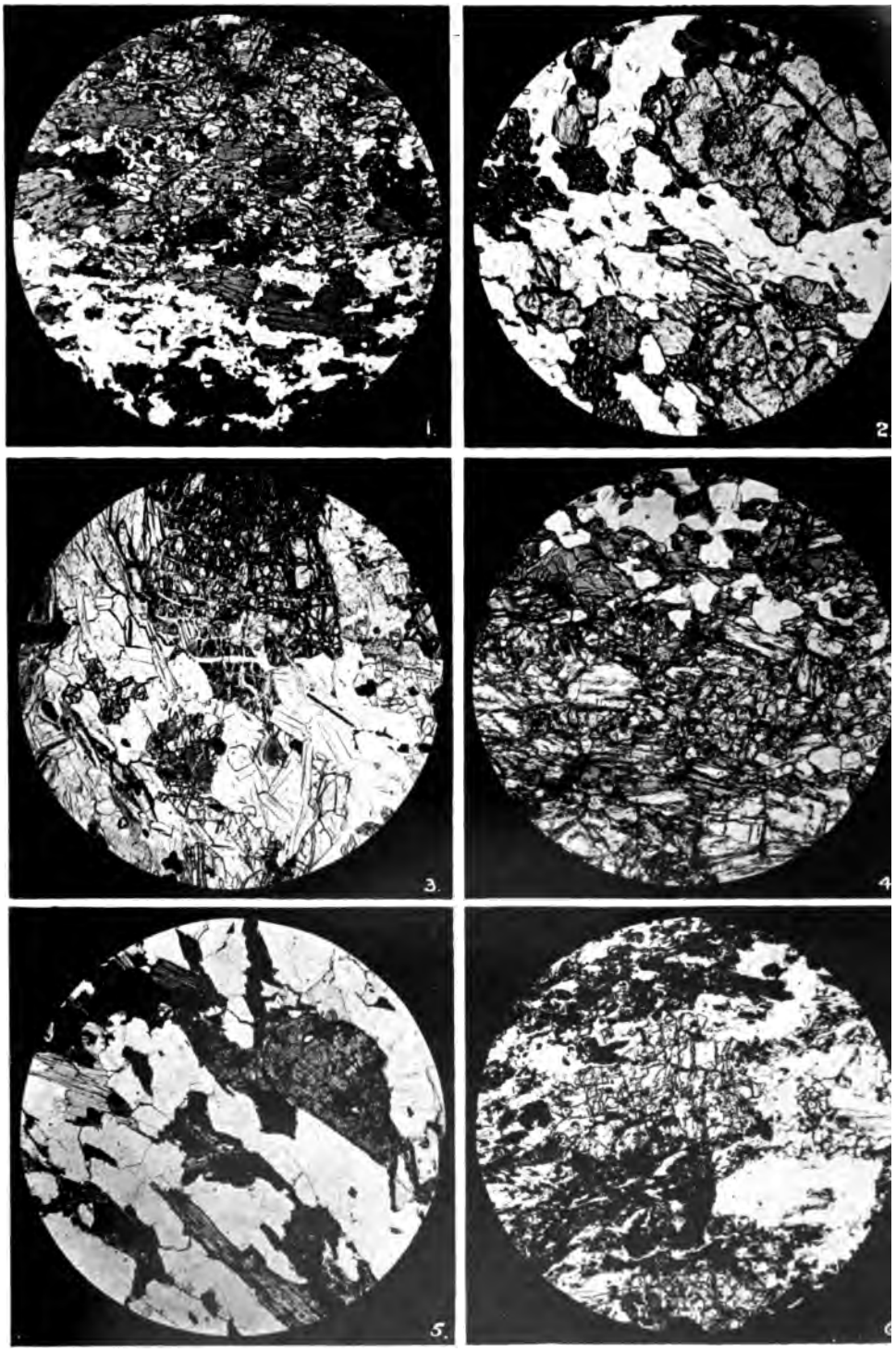

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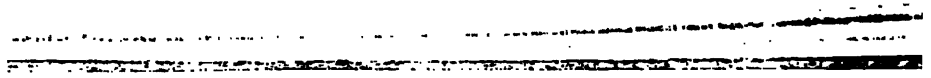

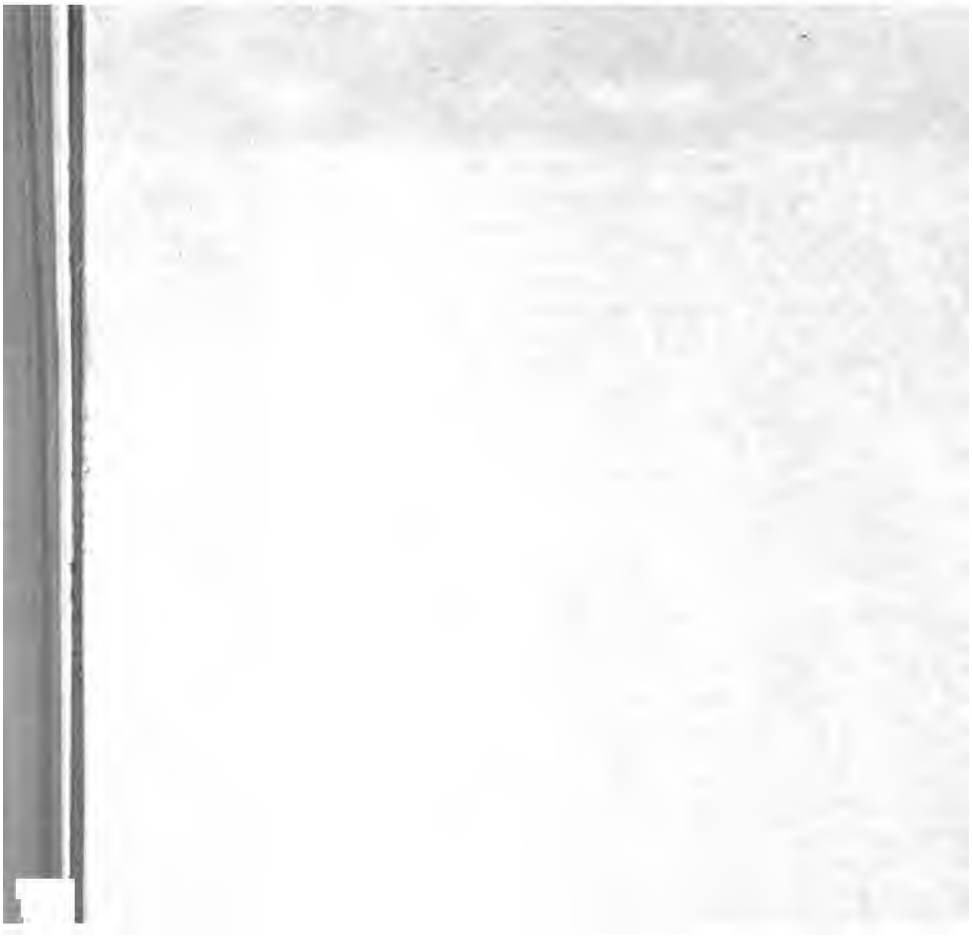
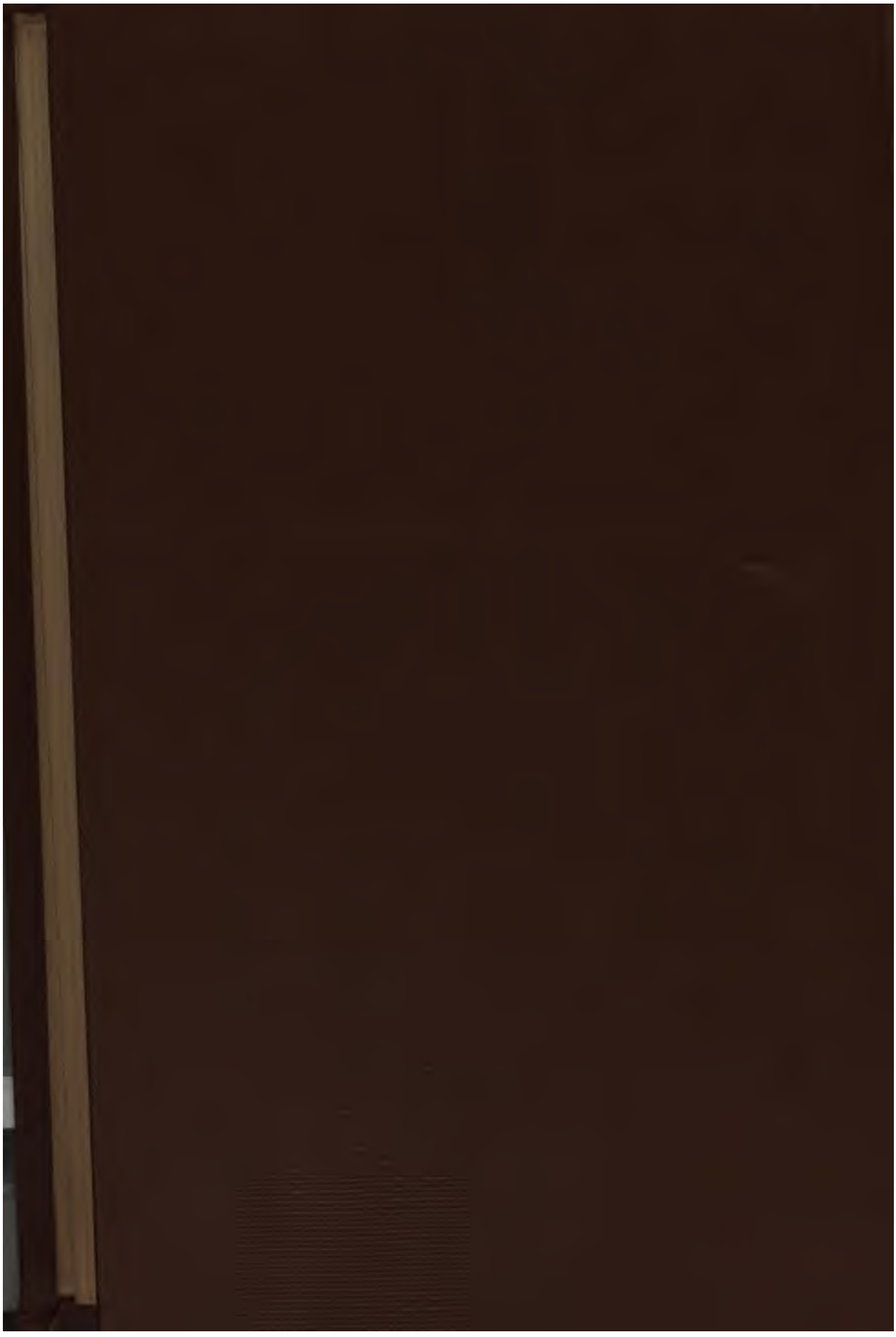
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